JOURNAL OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Random Noise

Modified Negative Perforation

Evaluating Film Steadiness

Sound on Color Prints

High-Speed Arc Photography

Forum on Theater Acoustics

Pulse Methods in Acoustic Analysis

Theater Acoustics in Scandinavia

American Standard

70th Semiannual Convention • October 15–19 • Hollywood

AUGUST 1951

Society of Motion Picture and Television Engineers

JOURNAL VOL. 57 AUGUST 1951 No. 2

Subscription to nonmembers, $12.50 a year; to members, $6.25 a year, included in their annual membership dues; single copies, $1.50. Order from the Society's General Office. A 10% discount is allowed to accredited agencies on orders for subscriptions and single copies. Published monthly at Easton, Pa., by the Society of Motion Picture and Television Engineers, Inc. Publication Office, 20th & Northampton Sts., Easton, Pa. General and Editorial Office, 40 West 40th St., New York 18, N.Y. Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

PRINTED BY MACK PRINTING COMPANY, EASTON, PA.

Data on Random-Noise Requirements for Theater Television

By PIERRE MERTZ

Provisional evaluation of permissible random noise for theater television is considered from several sources of information. These cover broadcast television experience and the graininess in motion picture film; the requirements deduced from the various sources generally agree. For broadcast television, a frequency weighting and limit on weighted noise power have been used. The finer picture detail of theater television presumes a lower permissible random noise. Changes in weighting curve are discussed. A limit figure of noise is suggested, which is comparable to graininess effects in motion pictures, though slightly more severe than present published performance on camera tubes.

1. Introduction and Digest of Conclusions

A DEFINITIVE EVALUATION of the random noise which is permissible in theater television will need to be made, of course, with theater television equipment. In the meantime, certain deductions can be drawn from other sources to permit the estimate of a provisional figure which can eventually be checked.

In the first place, data can be examined, which have been obtained for the setting of random-noise requirements for 4-mc broadcast television. Though the solution of this problem is not definitive either, experience with it has indicated that at present the best, simple answer consists in weighting the frequency distribution of the random noise, and measuring the rms amplitude of the weighted noise wave, as compared with the peak-to-peak amplitude of the television video signal (from tip of synchronizing pulse to maximum white level). Then the effect of varying amounts of weighted noise upon a picture is submitted for judgment to a group of observers. They are given a set of preworded comments to use as criteria of impairments. The list is reproduced below.

1. Not perceptible;
2. Just perceptible;
3. Definitely perceptible, but only slight impairment to picture;
4. Impairment to picture, but not objectionable;
5. Somewhat objectionable;
6. Definitely objectionable; and
7. Not usable

To be noted, particularly, are comments No. 2, "just perceptible," and No. 4, "impairment to picture, but not objectionable."

With a picture of excellent quality by

Presented on May 1, 1951, at the Society's Convention in New York, by Pierre Mertz, Bell Telephone Laboratories, Inc., 463 West St., New York 14.

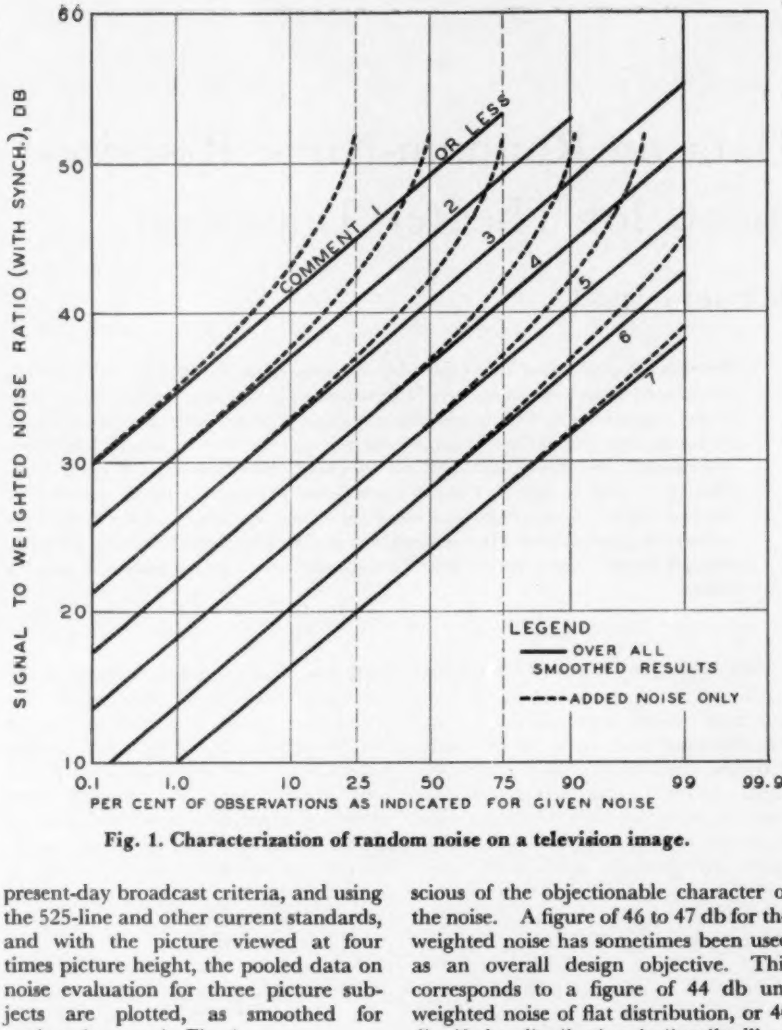


Fig. 1. Characterization of random noise on a television image.

present-day broadcast criteria, and using the 525-line and other current standards, and with the picture viewed at four times picture height, the pooled data on noise evaluation for three picture subjects are plotted, as smoothed for engineering use, in Fig. 1.

Examination of this shows that at a weighted noise somewhere between 40 and 50 db below the signal, 50% of the observers voted "comment No. 2 or less," i.e., they just begin to perceive the noise. Ninety per cent of the observers voted "comment No. 4 or less," i.e., the remaining 10% are just becoming conscious of the objectionable character of the noise. A figure of 46 to 47 db for the weighted noise has sometimes been used as an overall design objective. This corresponds to a figure of 44 db unweighted noise of flat distribution, or 40 db, if the distribution is "uptilted" or peaked toward the upper frequencies.

The weighting function to be used with Fig. 1 is again not definitive, but some of our best knowledge of it at present is plotted as curve I of Fig. 2.

The discussion which is presented below leads to the conclusion that for an 8-mc theater television system exactly

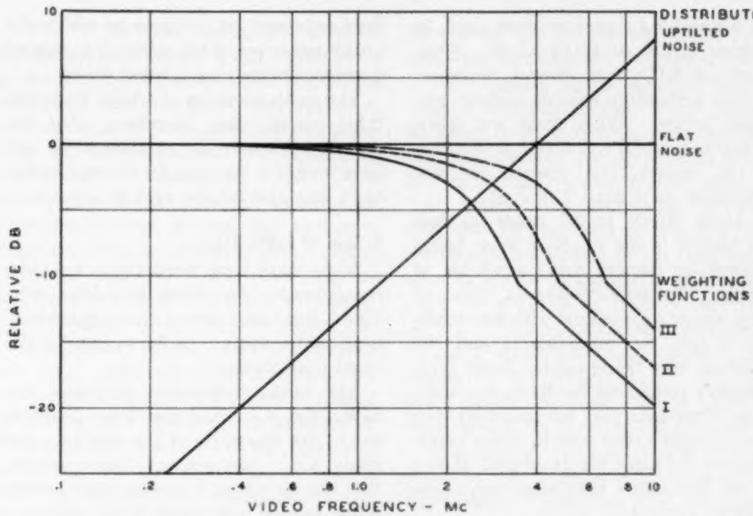


Fig. 2. Weighting functions and random-noise distributions.

the same plot as shown in Fig. 1 can be used provisionally. The weighting function to be used, however, is that indicated by curve III of Fig. 2. These indications assume that the system uses in the order of 740 scanning lines. If the broadcast standard of 525 lines is continued, and the frequency band merely widened to 8 mc, the weighting curve I is to be used, but the acceptable weighted noise reduced 3 db, i.e., the plots of Fig. 1 can be used, with the figures marked in the ordinates all increased numerically by 3 db.

These deductions all contain, either implicitly in the new weighting function or explicitly where the same weighting function continues to be used, a factor of 3 db greater severity in the requirement imposed. This is an estimate of the influence of the higher quality of the 8-mc theater television image (in the form of increased sharpness) as compared with the 4-mc image on which the data were taken.

Analogous figures have been reported by RCA, reached by means of a different philosophy, as will be discussed below. Their figure, translated into the terms which have just been used, is 50 db.

An obvious comment which can be made on the experiments used for plotting Fig. 1 is that they were carried out on a screen which was adequate in size for the testing of home viewing of broadcast television, but which was too small for the testing of theater television. There is evidence to show, however, that if the image subtends the same angle at the eye (which is controlled by setting the ratio of viewing distance to picture height), the results are very little dependent upon its absolute size.

A second estimate of permissible random noise in theater television pictures can be deduced from a study of the photographic graininess in present-day motion pictures. Although this graininess is perceptible to a watchful observer in a good seat, it is not obtrusive and not considered a problem by the motion picture industry. It can, therefore, serve as an index of how much of this impairment is acceptable. A simple deduction on the amount of this noise as derived from sound-track measurements indi-

cates a weighted signal-to-noise ratio, in television terms, of 47 to 52 db. Otto Schade of RCA has shown, however, that this deduction ignores certain important points. When these are taken into account, the result is not as definite, but the figures, less severe, are not changed by more than 2 or 3 db.

A third check to be made against these figures is the random noise being delivered by camera tubes available at present. The performance of these, of course, varies a great deal with the conditions of use, the adjustments and the individual tube being used. Some typical figures published by RCA (in addition to some informal information) give signal-to-noise ratios which, when translated into the same terms as used above, are, for broadcast television use, those shown in Table I.

Table I

Camera tube		*Signal-(peak-to-peak, including synch.)to-weighted noise ratio*
1850A	iconoscope	44 db
5655	image orthicon	44 db
5769	image orthicon	below above figure
5820	image orthicon	40 db
5826	image orthicon	43 db
1848	iconoscope	39 db
2P23	image orthicon	36 db

The best of these, therefore, formally miss the tentative overall design objective by 2 or 3 db, without allowance for contribution to noise from any other sources. It should be understood, of course, that new tubes are likely to be under development with better figures on noise performance.

A Bell Laboratories film scanner gives a signal-to-weighted noise ratio, in the above terms, estimated at 46 db. The data of Fig. 1 were taken with this signal source and, as taken, follow approximately the dotted lines. The solid lines represent an estimate in which the ordinates cover total noise (i.e., signal generator noise plus applied noise).

The indications as a whole from this third check are, therefore, that for theater television the random noise will be a problem not only for the connecting links, but also for the pickup apparatus.

2. Use of 4-Mc Data

Some data have been taken on noise requirements for 4-mc broadcast television channels, and a first approximation of the theater problem can be derived from them.

The major difference, of course, between the 8-mc and the 4-mc channels lies in the sharpness of the resulting picture. One may expect, consequently, that the viewer will measure the random noise against the finest detail which it obscures or distorts, and therefore to that extent he will be more critical of the 8-mc than of the 4-mc random noise. One can even propose, as probably reasonable, a principle that the viewer will consider equally objectionable, equal rms amplitudes of a "flat" distribution of random noise up to cutoff in the 4-mc channel and a similar "flat" distribution to cutoff in the 8-mc channel. This will be referred to below a number of times and will henceforth be merely called "the proposal." At the same viewing distance, the 8-mc band granulation would obviously be less visible than the 4-mc band granulation of the same amplitude, and the proposal amounts to making this difference in visibility a quantitative estimate of how much more critical the observer is in the case of the 8-mc picture than he is in the case of the 4-mc picture. If the proposal is taken as a guide, it means that with a "flat" distribution the total noise power in the 8-mc channel would be set at the same value which is acceptable for the 4-mc channel. This means that the tolerable noise power per kc of bandwidth is set at 3 db lower in the 8-mc than in the 4-mc channel.

M. W. Baldwin discovered experimentally, some time back,[1] that in a given television system the impairing effect of a flat "low-pass" distribution of random noise is measured largely by the noise power per kc, and is substantially independent of the upper cutoff. This means that if one uses this measure of how much more critical the viewer is expected to be, according to the proposal, of 8-mc than of 4-mc television, it amounts to a 3-db difference in admissible random noise. In the same experimentation it was also found that for equal impairing effect the random-noise power is raised 6 db for a doubling of the viewing distance. A measure of the expected reaction in the observer, according to the proposal, therefore, also corresponds to a reduction, in the ratio of 1 to $\sqrt{2}$, in the minimum viewing distance for which the system is to be engineered for 8 as compared to 4 mc.

There are other grounds for considering the proposal to be reasonable. These are that the added fine detail signal in going from a 4-mc to an 8-mc band is lower on a power-per-kc basis than the signal already existing in the 4-mc band. General typical indications are that the average signal power per kc at 8 mc is $\frac{1}{4}$ that at 4 mc. The average power per kc of the added signal would, therefore, be somewhere between equality and $\frac{1}{4}$ of that at the 4-mc cutoff. The noise power per kc in the band between 4 and 8 mc, for the 8-mc system, as set by the proposal, is just half that in the 4-mc system. Half happens to be the mean proportion between 1 and $\frac{1}{4}$. Thus, on the new detail, added between 4 and 8 mc, the signal-to-noise ratio, to at least its mean proportional, is kept at the figure maintained in the 4-mc system at 4 mc. There is, of course, an improvement of 3 db in the signal-to-noise ratio between 0 and 4 mc, which is one of the factors contributing to the improved quality of the 8-mc over the 4-mc system. The consequences of the proposal, when increasing the bandwidth from 4 to 8 mc, may be examined in more detail.

For Case I it will be assumed that the number of scanning lines is not changed in going from 4 to 8 mc. Diagrams of the two observed pictures are illustrated in Fig. 3, each viewed at four times picture height. The scanning-line structure will be identical in the two cases. The finest horizontal detail that can be seen in the 8-mc picture at (b) is, however, twice as fine as in the 4-mc picture at (a). This is indicated schematically by marks which are proportional to cycle marks in the two. At (a), the 4-mc cycle marks will have exactly twice the spacing that the 8-mc marks have at (b).

The theory that was presented in the paper on "Perception of Television Random Noise,"[1] indicates that the simplified noise-weighting curve presented there for a four-times-picture-height viewing distance is merely extended from 4 to 8 mc. This is illustrated by curve I of Fig. 2. It is to be noted, by reference to the original paper, that under the conditions then used in the experiment most of the weighting was visual, i.e., in the eyes of the observer. The picture tube used contributed somewhat, estimated at about a third to a quarter of the final effect. In Fig. 2 this double source of the weighting is ignored.

For Case II it will be assumed that the number of scanning lines in the 8-mc system is increased, in the ratio of $\sqrt{2}$ to 1, to that in the 4-mc system. This is illustrated in Fig. 4. Fig. 4(a) is merely a duplication of Fig. 3(a). The solid lines in Fig. 4(b) are a duplication of Fig. 3(b), except for the cycle marks. Since the number of scanning lines has been increased in the ratio $\sqrt{2}$ to 1, the horizontal speed of tracing them has been increased in the same ratio. Thus, the 8-mc cycle marks no longer have half the spacing of the 4-mc cycle marks in (a); they now have $1/\sqrt{2}$ times the spacing of the latter.

Inside of Fig. 4(b), in dotted outline, is

a picture frame that covers the same number of scanning lines vertically as used in the 4-mc system of Fig. 4(a). It therefore has $1/\sqrt{2}$ times the vertical height of the picture in solid lines. The remainder of the picture frame is drawn in to the same scale, i.e., its width is $1/\sqrt{2}$ times that of the one in solid lines. The cycle marks are shown with exactly the same spacing as the 8-mc cycle marks in the picture with solid lines.

It will be noted that, except for its absolute size, which is reduced in scale in the ratio of 1 to $\sqrt{2}$, the dotted-line picture of Fig. 4(b) has exactly the same objective capabilities for rendering detail, with the 8-mc band, that Fig. 4(a) has with its 4-mc band. It will also objectively render random noise in exactly the same way, provided the instantaneous time scale of the noise is stretched in the ratio of 2 to 1, because the cycle marks at 8 mc in Fig. 4(b) have exactly the same proportionate spacing to the frame that they have in Fig. 4(a) at 4 mc. The dotted picture in Fig. 4(b) is viewed at $4\sqrt{2} = 5.65$ times picture height. Thus, noise will be seen in Fig. 4(b) in exactly the same way as in the 4-mc picture of Fig. 4(a) viewed at 5.65 times picture height, but with the noise-frequency scale stretched from 4 mc to 8 mc. If the source of the weighting is ascribed to the eyes of the observer alone, and the picture-tube contribution ignored, the noise-weighting curve for Fig. 4(b) is that for Fig. 4(a), viewed at 5.65 times picture height, stretched on the frequency scale so that the 4-mc point appears at 8 mc. This weighting curve is shown at II in Fig. 2.

We do not contemplate setting the noise for the 8-mc channel in Fig. 4(b) equal in absolute perceptibility to that for the 4-mc channel in Fig. 4(a), but it will be of some interest to examine what this leads to.

What is involved in the proposal, in terms of Fig. 4(b), is to engineer the 8-mc system in terms of a viewing distance that permits the fine detail in the dotted-line frame to be equal to that seen in Fig. 4(a). This is accomplished by reducing the viewing distance to $4/\sqrt{2}$ or to 2.83 times picture height. This has been done in Fig. 5(b) and will represent Case III.

Figure 5(a) is again a duplication of Figs. 3(a) and 4(a). The dotted-line picture in Fig. 5(b) is also exactly the same in objective representation of detail. The dotted cycle marks in Fig. 5(b) are spaced exactly the same as in Fig. 5(a), but represent 8-mc cycles instead of 4-mc cycles. Then the solid lines in Fig. 5(b) are scaled up in the ratio of the $\sqrt{2}$ to 1 about the dotted lines, except for the cycle marks, which are kept at the same 8-mc spacing. The solid lines represent the complete picture transmitted by the 8-mc band viewed at 2.83 times picture height, according to the consequences of the proposal. The noise-weighting curve for Fig. 5(b) is, therefore, the same as that used for Fig. 5(a), except that it is stretched along the frequency scale so that the 4-mc point appears at 8 mc. This is shown by curve III in Fig. 2.

With this background, relations between the various cumulated weighted power requirements can be deduced for the three cases considered, first, under assumptions of equal absolute noise perception between the 4- and 8-mc bands, and then, under the proposed assumption of a somewhat more severe requirement for the 8-mc band. To correlate the results with two distributions of noise, approximated in practice, the weighted power ratios can then be translated into unweighted power ratios for those distributions. The distributions are illustrated in Fig. 2; they are the "flat," already mentioned, and the "uptilted," rising with frequency up to the cutoff point at the rate of 6 db per octave. The relations have been summarized in Table II.

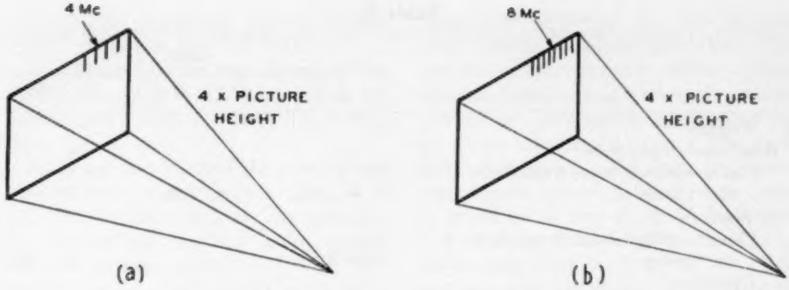


Fig. 3. Viewed 4-mc (a) and 8-mc (b) pictures. No change in scanning lines.

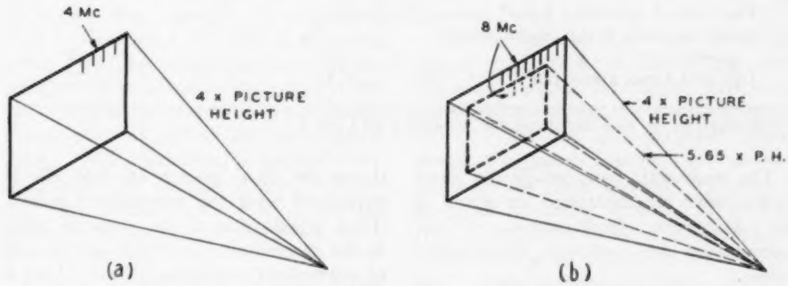


Fig. 4. Viewed 4-mc (a) and 8-mc (b) pictures. Scanning-line ratio 1: $\sqrt{2}$. No change in viewing distance.

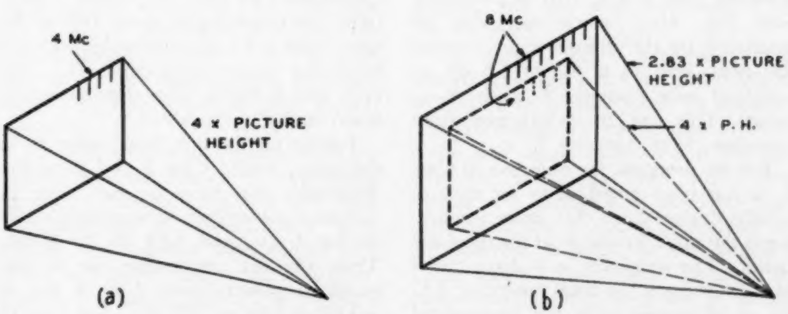


Fig. 5. Viewed 4-mc (a) and 8-mc (b) pictures. Scanning-line ratio 1: $\sqrt{2}$. Viewing-distance ratio $\sqrt{2}$:1.

Table II

	Cases		
	I	*II*	*III*
A. Weighted			
Equal absolute perception			
Flat or uptilted noise, 8 mc above 4-mc* power	0 db	1.5 db	
Proposal			
Flat or uptilted noise, 8 mc above 4-mc* power	−2.8		0 db
B. Unweighted			
Equal absolute perception			
Flat noise, 8 mc above 4-mc* power	2.8	2.8	
Uptilted noise, 8 mc above 4-mc* power	6.4	4.7	
Uptilted above flat noise, 4 mc	3.5		
Uptilted 8 mc, above flat 4 mc*	9.9	8.2	
Proposal			
Flat noise, 8 mc above 4-mc* power	0		0
Uptilted noise, 8 mc above 4-mc* power	3.6		0
Uptilted 8 mc, above flat 4 mc*	7.1		3.5

* Distribution up to 4 mc using the weighting of Case I

The basic data from which the items in the table are calculated are given in the Appendix. Explanations of the calculations are outlined immediately below.

For absolute equal perception in Case I, the weighted noise, either flat or uptilted, should be the same for the 4 and 8 mc, this, of course, being the objective of the weighting. For Case II, the closer scanning lines in Fig. 4(b) as compared with Fig. 4(a), which can also be measured by the difference in viewing distances, lead to a rise of 1.5 db in weighted noise from the 4- to the 8-mc band. This can be determined from equation (5) of reference 1.

For the proposal, the objective in Case I, as has been noted, is to set the unweighted cumulated flat noise requirement the same for the 8- as for the 4-mc band. The weighting to a sharp cutoff at 4 mc reduces the total power by 2.87 db as compared with the unweighted power (to the same sharp cutoff). The weighting to a sharp cutoff at 8 mc reduces the total power by 5.64 db as compared with the unweighted power. Thus, application of the proposal leads to the requirement for the 8-mc channel of a weighted total noise power which is 5.64 − 2.87 = 2.77 db lower than for the 4-mc channel. In each case the same curve I of Fig. 2 is used as the weighting function.

The objective in Case III is to set the requirement for the 8-mc weighted noise (with the weighting of curve III) at the same value as for the 4-mc weighted noise (with the weighting of curve I). This ratio then holds for other distributions of noise, including "uptilted."

Taking up the first item under B, in the table, under Case I and from the Appendix, the drop for flat noise in weighted power from unweighted is 2.87 db for 4 mc, and 5.64 db for 8 mc. Thus, the net permissible rise in unweighted power, from 4 to 8 mc, is −2.87 + 5.64 = 2.77 db. For Case II the respective figures are −2.87 and +4.21 db, but there is a differential of

1.5 db in weighted power, giving $-2.87 + 4.21 + 1.5 = 2.84$ db.

For uptilted noise the corresponding figures are $-6.34 + 12.72 = 6.38$ db for Case I, and $-6.34 + 9.56 + 1.5 = 4.72$ db.

At 4 mc the permissible unweighted uptilted noise, above flat noise, is $6.34 - 2.87 = 3.47$ db. At 8 mc the permissible unweighted uptilted noise, above flat noise at 4 mc, is $12.72 - 2.87 = 9.85$ db, for Case I. For Case III, it is $9.56 - 2.87 + 1.5 = 8.19$ db.

In the next group of items, covering the proposal, the first comes back to the original objective for Case I, namely that the 8-mc flat unweighted noise be placed at the same level as the similar 4-mc noise. For Case III, the weightings to 8 mc on curve III and to 4 mc on curve I give the same drop from flat unweighted to weighted noise, namely 2.87 db. This keeps the difference zero for the unweighted, as it did for the weighted noise. This also holds for uptilted noise in Case III, the drop here being 6.34 (or 6.35) db for each. For Case I, on this last item, the figures are $12.72 - 6.34 - 2.77 = 3.61$ db.

Finally, the uptilted 8-mc noise, above flat 4-mc noise, each unweighted and for Case I, is $3.61 + 3.47 = 7.08$ db. For Case III, the figures are $0 + 3.47 = 3.47$ db.

It is to be understood, of course, that the small fractions of db which are kept in the figures above are purely for the sake of internal consistency in the table, and do not pretend to imply such precision in knowledge of the correct weighting.

There have been many analyses of the random noise permissible in a broadcast television channel. Perhaps the most comprehensive of recent tests were carried out together with others presented in a paper[3] before the IRE Convention in March 1950. The reactions of observers to random noise in a television picture were determined, as expressed by preworded comments. The signal used followed the 525-line and other current broadcast standards. The pictures were observed under critical viewing conditions and were of excellent quality as considered by present-day broadcast television criteria. The highlight luminance and contrast ratio varied from picture to picture, in order to adjust to the best image in each case. The first ranged from 42 to 65 mL, and the second, from 26 : 1 to 130 : 1. The resulting data are shown summarized in Fig. 1. The dotted lines cover the effect of noise already existing in the film scanner used to generate the signal, and can be ignored for the moment. They will be discussed again below in connection with the noise originating in pickup devices.

The ordinates of Fig. 1 are plotted as signal-(peak-to-peak, including synchronizing pulses)to-weighted rms noise (weighted according to curve I of Fig. 2) ratio. Following the proposal made above, the curves can be used as they stand for the 8-mc band, if the noise is weighted according to curve III of Fig. 2, provided the number of scanning lines in the 8-mc system is raised from 525 to 741. If the number of lines is kept at 525, then according to the discussion the acceptable weighted noise power is reduced by 2.7 db. That is, the ordinates should be labeled with figures numerically 2.7 db (say, rounded to 3 db) greater, and the weighting curve I of Fig. 2 used.

The data for Fig. 1 were taken on a television picture 6 × 8 in., and it would be natural to question them for application to a theater-screen-size picture, even if the solid angle subtended at the eye were the same. In 1941 there were doubts of a similar kind, directed particularly at the sharpness perception of the observer to detail in the picture.[2] These existed particularly because of earlier data indicating a loss of visual acuity for near vision. The 1941 results indicated the earlier information to have been much exaggerated, and perception

to be fairly closely the same over the visual range of accommodation. The change in visual acuity, according to Luckiesh and Moss, is about 16%, and, according to unpublished experiments of Baldwin, about 4%. While data on the larger screen are eventually desirable, the curves of Fig. 1 are acceptable provisionally.

3. Photographic Graininess Data (Sound Track)

Film graininess has been an important problem for the motion picture engineer from the start, and there is much literature on the matter.[4] Simple quantitative data on the subject come from the use of film for sound track, of the variable-density type. A brief review of the data are given in an unpublished report presented by Dr. Otto Sandvik to the Subcommittee on Distribution Facilities of the Committee on Theater Television of the SMPTE.

The sound track is scanned by an aperture, 0.084 in. wide and 0.001 in. long (i.e., in the direction of motion). The sound system transmission is substantially flat from 50 cycles to 10 kc. The signal-to-noise ratio on such a system is of the order of 45 db. This is under optimum conditions, and it is more likely to be of the order of 40 db. These are the basic figures, before schemes of noise reduction, which cannot be employed in the picture, are used.

In order to interpret these figures in terms of pictorial representation it is necessary to know how the noise and signal are measured. The noise is measured by its rms amplitude. The signal is measured by the rms amplitude of a sine wave that is printed at an average diffuse density which is understood to be of about 0.6 in the film (transmission 25%) and to have an order of 8-db margin against a sine wave whose peaks just saturate on the zero transmission side. The usual method of expressing this ratio in the television art is to measure the noise by its rms amplitude, as here, but the signal is measured by its peak-to-peak amplitude. In a general way, the picture in a film runs from nearly zero transmission to some 80% transmission. Thus, the following corrections are needed to translate from the sound signal to the picture signal:

3 db	rms to peak-to-zero
6	peak-to-zero to peak-to-peak
8	margin, peak-to-peak
4	50% to 80% transmission range
21 db	total

In addition, television measurements are usually expressed with respect to a signal wave including the synchronizing pulse, which is some 2.5 db greater in peak-to-peak amplitude than a signal wave including only the picture. Thus, this figure should be added, giving a final correction of 23.5 db. This gives 68.5 db and 63.5 db, respectively, for the optimum and typical figures.

The next step involved in the interpretation is to correct for the aperture spot size, which is, of course, not the sound-track scanning-aperture size. An 8-mc theater television system of 741 lines ($525\sqrt{2}$) will be assumed. This has 700 unblanked lines, and there are 590 half-cycles of the 8-mc wave along the unblanked length of a scanning line. Thus, the aperture spot size as measured on the film is 0.905×1.46 mils. It has an area of 1.32 sq mils, as compared with the 84 sq mils of the sound-track aperture. Graininess distribution is approximately a normal distribution,[4] or its spectrum is approximately flat, so that the power ratio correction is very closely the area correction. This is 64 to 1, or 18 db, which must be subtracted from the signal-to-noise ratio which has been mentioned above.

There is an additional correction to be made for the difference in repetition rate between motion picture frames and complete television frames, which affects the storage of the visual perception. When the flicker is imperceptible, this is

approximately in the ratio of the repetition rates for the noise power. This is 30/24, or about 1 db, which changes the 18 db above to 19 db.

Since the noise spectrum is flat, the weighting, with curve III of Fig. 2, requires a further numerical addition of 2.9 db, changing the 19 db to 16 db.

Thus, it is simply deduced that for theater television the weighted random noise corresponding to motion picture graininess is slightly over 52 db under optimum conditions, and slightly over 47 db under more usual release-print conditions.

Dr. Sandvik also refers to some figures presented by Otto H. Schade in the *RCA Review*[5] (p. 36, Mar. 1948). These are based on a Fechner fraction of 2% [see his equation (18)], but are said to be in substantial agreement with values observed on high-quality 35-mm film. They come out, respectively, (unweighted) 37 and 33 db, for 500- and 800-line systems. The signal basis is $\overline{B}$, or average scene luminance (average over the frame). The average, from frame to frame, has been investigated[6] and found, for black-and-white feature films, to be of the order of $\frac{1}{5}$ the maximum. It is obviously glib to substitute this for the average over the frame, but the order of magnitude appears right. Thus, there should be added 14 db, plus 2.5 db for synchronizing signal, less 1 db for frame-speed ratios, and plus 2.9 db for weighting. The result is slightly over 51 db for the 800-line system. This is admittedly rough and ready, but in agreement with the previous figure.

It may be noted that Schade, in the reference which has just been quoted[5] has given a further estimate, which he entitled "Threshold Signal-to-Noise Ratios Required for High Quality" (*RCA Review*, p. 283, June 1948). These are for a 4-mc channel rather than for theater television, and are not derived directly from graininess data but from threshold visibility on a picture tube. They are, nevertheless, of interest here. They are for a picture of 32-ft-L highlight luminance, viewed at four times picture height, and do not include the 2.5-db allowance for synchronizing pulse. The figures are:

Flat noise.	50–54 db
"Peaked" noise (uptilted)	40–48 db

These figures are more severe than the ones quoted by Sandvik. The figures are for unweighted noise, and it is noted that the difference ranges from 6 to 10 db between the uptilted and flat noise requirements, as compared with differences for the weightings of Fig. 2 ranging from 3.4 to 7.1 db. This indicates somewhat sharper weighting functions than are shown in Fig. 2.

This difference will be found to occur in a number of instances in the present report. Examination of the discussion of the weighting function by Schade indicates that he conceives of it as describing a filtering phenomenon which is the same for single-frequency bars as for random-noise grains, and for which he has determined the characteristics from bar patterns. However, it is to be noted that experiments with bar patterns have indicated a rise of threshold amplitude with frequency[7] (near the upper portion of the video frequency range) at the rate of 12 db per octave. Experiments with random noise[1] (resulting in the weighting of Fig. 2) indicate a corresponding rise of only 6 db per octave. While the question does need to be resolved, the weighting of Fig. 2 is considered, for the moment, safer than the steeper function used by RCA authors.

Sandvik further refers to some figures of Jones and Higgins on granularity. These will be discussed in Section 4 below.

4. Photographic Graininess Data (Picture)

In a paper presented orally before a meeting of the Subcommittee on Interconnecting Facilities, Schade has pointed out the oversimplifications in some of the

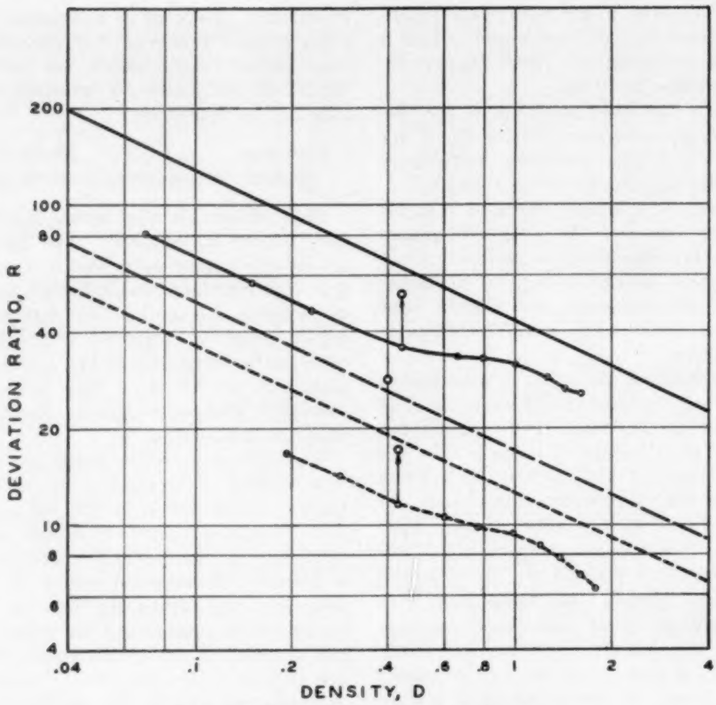


Fig. 6. Graininess variation with density.
———Fine grain—Pos. 1302; Neg. 1203
– – – –Plus X - - - - -Super XX
Straight lines, Schade; points, Jones & Higgins

deductions in the previous section. These are chiefly:

(a) The grain structure in photographic film does not enter into the picture, as a function of density, in the same manner as does random noise in a television picture as a function of local luminance (say, measured in terms of equivalent density below highlight luminance).

(b) The translation between electrical signal voltage and picture luminance is not usually linear.

Schade notes that the law of variation of granularity (expressed as a standard deviation of local transmittance divided by average local transmittance) with density, in a single film, is as the square root of the latter. That is,

$$\Delta T/T = k_1 \sqrt{D}, \quad (1)$$

where

T = transmittance,
ΔT = standard deviation of transmittance,
D = density = $\log_{10}(1/T)$,
k_1 = a constant.

He frequently uses the reciprocal $R = T/\Delta T$, in which case:

$$R = 1/(k_1 \sqrt{D}). \quad (2)$$

Because photographic graininess follows an approximately normal law, R can be taken as proportional to the diameter of

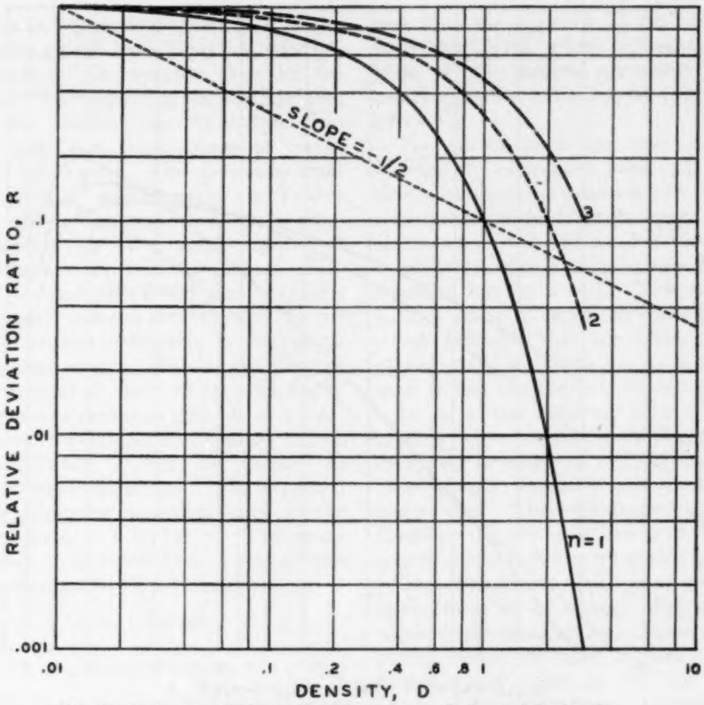


Fig. 7. Noise equivalent to graininess variation with density.

the sampling aperture used in measuring the graininess.

A plot summarizing Schade's measurements is compared in Fig. 6 with the results reported by Jones and Higgins[8] (p. 203, 1946). The connected points were measured by the Selwyn method, the isolated points by the Goetz and Gould method, and data for various sizes of aperture have been corrected to that for a diameter of 30μ (1 micron = $1\mu = 10^{-6}$ meter = 10^{-3} mm) for which the Schade data are presented. It is not likely that the films referred to are the same. The intermediate film is known to be different, i.e., Plus X for the Schade data and Panatomic X for the Jones–Higgins data. Considering this, and differences in actual samples and development, and also the differences in measurements of the same films by two different methods, the data of Fig. 6 represent a good check.

If the television receiving system reproduced picture luminance (or therefore also equivalent transmittance) were directly proportional to signal voltage and the noise were of a simple additive type, then ΔT in equation (1) would be a constant independent of T or D. Calling this k_2:

$$\Delta T = k_2 \tag{3}$$

$$R = T/\Delta T = T/k_2. \tag{4}$$

Thus, the ratio, R is proportional to T. Putting the constant k_2 as 1, this leads to the curve marked $n = 1$ in Fig. 7, which plots relative R as a function of density. The curve for this simple con-

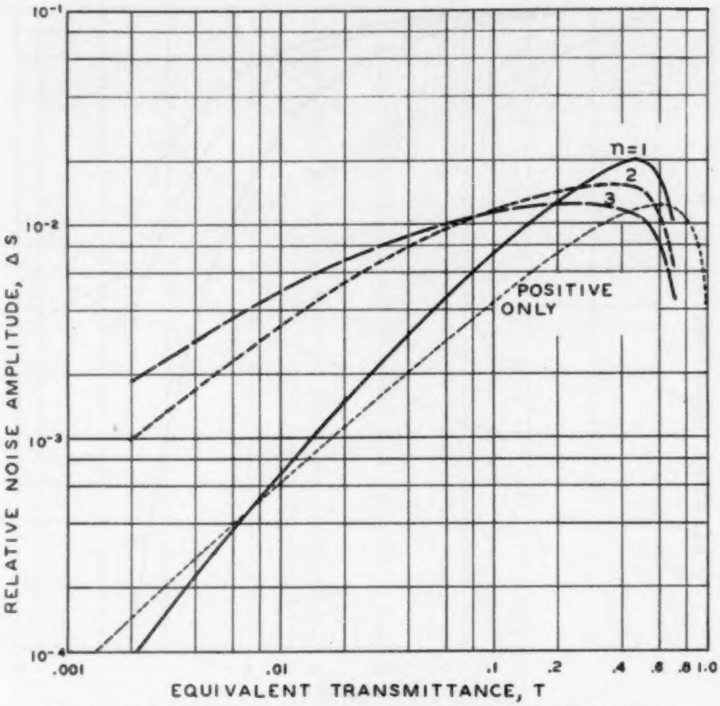


Fig. 8. Noise equivalent to graininess variation with transmittance.

ception of a television system is seen to be different from that obtained in a single film, exemplified by the line of slope $-\frac{1}{2}$.

The television receiver may be complicated somewhat by making the transmittance proportional to some power, n, of the signal voltage. That is,

$$T = k_3S^n, \quad (5)$$

where

S = signal voltage,
k_3 = a constant.

Then:

$$\Delta T/T = k_3n\Delta S/S \quad (6)$$

$$R = T/\Delta T = S/(\Delta Sk_3n) \quad (7)$$

$$= (T/k_3)^{1/n}/(k_3n\Delta S) \quad (8)$$

$$R = T^{1/n}k_4, \quad (9)$$

where:

$$k_4 = k_3^{1/n}/(k_3n\Delta S).$$

Most actual television receivers follow a law in which n has some value between 2 and 3. The plots of relative R for these values, assuming in each case k_4 as equal to 1, are indicated in Fig. 7. They represent a slightly better fit than for $n = 1$, only, however, in that the general slope tends to be somewhat closer to $-\frac{1}{2}$.

Schade points out, furthermore, that actual motion picture film, as projected on a screen, is more complicated than a single emulsion. It consists of a negative printed on a positive, which is projected through an optical system. The emulsion having the greater graininess is usually the negative, because the

stakes in higher film speed (and consequently greater graininess) are more important for the negative than for the print. The negative graininess is printed on the positive with an inverse density scale (i.e., black turns to white, and vice versa). The graininess contribution of the negative is further changed by the gamma of the positive emulsion and by a small amount of blurring in the printing process. Finally, the graininess of the positive print is somewhat reduced in projection by the small amount of blurring in the optical projection process. Schade goes through estimates of all these effects, and finally ends with a deviation ratio, R, as a function of the equivalent density, D, or transmittance, T, of the picture as projected on the screen. This is plotted in a somewhat modified form, as the curve for $n = 1$ in Fig. 8. The modification is obtained from a transformation of equation (8) by placing:

$$k_5' = 1/(k_3 \cdot k_2^{1/\gamma}).$$

Then,

$$\Delta S = k_5 T^{1/n}/(nR). \qquad (10)$$

The curve for $n = 1$ then represents ΔS as a function of T for k_5 and n, each equal to 1. In a simple transmission system having a receiver characteristic for which $n = 1$, the quantity ΔS, representing the rms value of the superposed noise, would be independent of the instantaneous magnitude of the signal or of its corresponding screen luminance, and would thus be represented as a constant in Fig. 8. The curve, however, shows how it must vary with the relative screen luminance to correspond with the effect obtained from the composite photographic graininess as deduced by Schade.

To show the effect of taking account of the negative graininess and the other factors, the fine-dotted curve marked "positive only" in Fig. 8 is a reproduction, in the transformed coordinates, of the straight line for fine-grain film of Fig. 6. The blurring effects more than compensate for the graininess contribution from the negative, in the very extreme highlights, where the equivalent noise of the positive graininess alone comes out greater than for the composite effect.

The curves have also been plotted showing the equivalent noise, ΔS, for a simple transmission system where the receiver characteristic has the more usual exponents $n = 2$ and 3. For these the equivalent noise is much more nearly constant than for $n = 1$. Nevertheless, it does show a range of equivalence, which indicates that the incidence of photographic graininess is not wholly the same as that of additive random noise.

In an actual receiving tube the exponent, n, is approximately constant only over a range of luminances, and drops deeply toward the lowest luminances used. The equivalence in Fig. 8, therefore, departs even further than suggested, for the very low transmittances.

The equivalence which is of greatest significance is, of course, that which occurs in the transmittance region of the picture where the noise is most visible. Unfortunately, this is not too well known at the present time. However, in the same communication, Schade presents the results of some threshold measurements of random noise as a function of the picture luminance where the noise is perceived. A replot of his curve, for noise perceived on picture modulated fields, is shown in Fig. 9, translated into the same coordinates as Fig. 8. His curve has been translated to 15 ft-L equal 100% transmittance.

The fact that the curves run below those for the same indices in Fig. 8, in some part of the transmittance range, indicates that the photographic graininess for which Fig. 8 is plotted will be above threshold for those transmittances. This is consistent with the statements which have been made before. The margin runs in the order of 5 db and is at its maximum in the transmittance region between 0.15 and 0.3. If a constant additive noise were superposed, of a

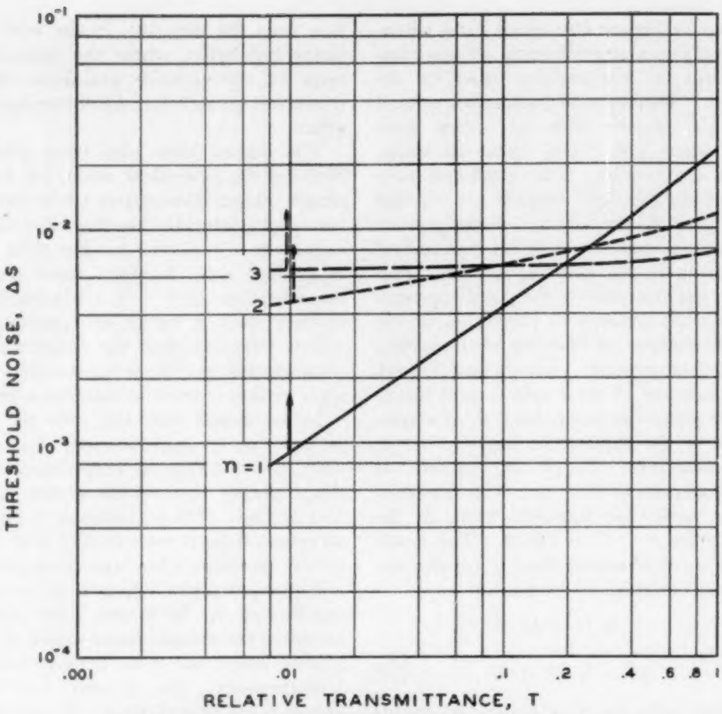


Fig. 9. Threshold noise—variation with transmittance.

value indicated at the point of maximum margin of visibility over threshold, it would appear worse than the graininess portrayed in Fig. 8, because the margin of visibility over threshold would be greater in the lower transmittances. To obtain a constant additive noise showing about the same picture impairment as the photographic graininess, the margin of visibility of the latter has been translated to the region of greatest susceptibility, i.e., in Fig. 9, of lowest transmittance, which has arbitrarily been taken as 0.01. (There might be some question as to whether, in consequence of the remarks made regarding Fig. 8, this is not too low for validity in actual receivers.) Under these conditions the noise equivalences are (measured to the signal at 100% transmittance):

$n = 1$	55 db
2	42
3	38.

These are indicated by the tips of the arrows at the left end of the curves in Fig. 8. The figures need further corrections as follows:

+2.5 db	ratio of effective apertures (44μ diam to 1.32 mils[2])
−1.	ratio of frame rates
+2.5	addition of synchronizing pulse
+2.9	frequency weighting
6.9	net
say, +7	(rounded)

Thus, the figures above deduced are changed to:

$n = 1$	62 db
2	49
3	45.

These figures, ignoring the case for $n = 1$, are slightly more lenient than, but in substantial agreement with, those derived from sound-track data. They are somewhat suspect for two reasons. First, the aperture data imply a poorer projected-film picture than television picture, which does not appear wholly reasonable. In the second place, the random noise is shown to be first perceived in the extreme blacks, which is contrary to general observation. This is caused by the trend of the curves in Fig. 9, which does not show the usual rise of threshold noise to a constant toward low luminances, which again is the indication of deviation from the Weber–Fechner law.

In a general way, it can be said that while the discussion of the detailed points has clarified our understanding of the relationship between photographic graininess and random noise, it has not seriously changed the conclusions from the simple sound-track deductions.

Schade has also compared the incidence of noise in the image orthicon camera with that of photographic graininess. This correlates somewhat more closely than that of the additive noise in the simple circuit. Computing this noise to threshold leads to a requirement of 45 db to the maximum picture signal. This is corrected to 42 db by the change from 4 to 8 mc (i.e., without the change of observer viewing distance involved in the proposal which has been made above). By allotting a contribution of 6 db below this to "video amplifiers or signal distribution systems," the figure of 48 db is reached. To allow for superposition of the synchronizing signal, 2.5 db should be added to this and for conversion to weighted noise, 5.6 db should be added to the 8-mc figure, and 2.9 db to the 4-mc figure. Both, then, lead to 50-db weighted noise overall, and 56 db allocated to the electrical transmission. This allocation has not been made in any of the other figures presented, which merely deal with overall requirements.

5. Noise Data on Pickup Equipment

Some modern television pickup tubes have been described recently in the *RCA Review*,[9] and their signal-to-noise ratios are estimated under reasonably typical lighting conditions as adapted to their respective uses.

The 1850A iconoscope (photocathode image area, 17 sq in.) is estimated to have an unweighted signal-to-noise ratio of 35.6 db. With synchronizing pulse, this becomes 38 + db. This is a "peaked" or "uptilted" noise, and the equivalent flat noise is estimated in the paper at 45.1 db (with synchronizing pulse 48 − db). The allowance for the "uptilted" over the flat noise is, therefore, assumed at 9 to 10 db, compared with the 3.4 db which has been deduced above. This discrepancy in weighting has already been noted. Using the weighting of Fig. 2, the weighted figure would be 44 + db (with synchronization).

The 1848 iconoscope (photocathode image area, 6 sq in.) is estimated as having an unweighted signal-to-noise ratio of 29.8 db (with synchronizing pulse 32 db). This noise is characterized as "not always acceptable." The noise is also "peaked," and, using the weighting of Fig. 2, the figure would be 39 − db.

The 2P23 image orthicon (photocathode image area, 1.23 sq in.) is estimated as having, with the original gun design, an unweighted signal-to-noise ratio of 28 db (with synchronizing pulse 30 + db). With a new gun design this was raised to 30.9 db (with synchronizing pulse 33 + db). This is a "flat" noise, and no extra allowance is due. However, weighted noise (with the weighting of Fig. 2) would be 36+ db. The performance from the standpoint of noise is characterized in the paper by the statement, "Although this value is on the low side, it is acceptable for outside pickups."

The 5655 image orthicon (photocathode image area, 1.23 sq in.) is

Table III

	Distribution	
	Flat	*Uptilted*
Sharp cutoff to 4 mc		
Integrated, unweighted power	0	−4.77* db
Unweighted/weighted power, curve I	2.87	6.34
Unweighted/weighted power, curve II	1.66	3.30
Unweighted/weighted power, curve III	0.90	1.60
Sharp cutoff to 8 mc		
Integrated, unweighted power	3.00	4.26* db
Unweighted/weighted power, curve I	5.64	12.72
Unweighted/weighted power, curve II	4.21	9.56
Unweighted/weighted power, curve III	2.87	6.35
*Sloping cutoff to 5 mc***	*Flat*	*"Coaxial"***
Unweighted/weighted power, curve I	2.2	6.9 db

* In this distribution the watts per kilocycle have been set as equal at 4 mc to the watts per kilocycle in the flat distribution.

** See reference 1.

estimated as having an unweighted signal-to-noise ratio of 38.1 db (with synchronizing pulse 41 − db). This is flat, so that with the weighting of Fig. 2, the weighted figure would be 43.5 db. Compared with the 2P23 tube, the performance is characterized, "This gain in signal-to-noise ratio is very worth while and makes the tubes acceptable for studio application." It is understood, informally, that for good tubes the figure of 38.1 db is likely to rise to a little over 40 db.

The 5769 image orthicon (same size of photocathode image as 2P23 and 5655) is described, but no figures given on signal-to-noise ratio except the statement, "The 5655, however, is superior in its signal-to-noise ratio. . . ."

The 5820 image orthicon (same size of photocathode image as others) is described in the more recent paper of the reference, but no statement is made as to its signal-to-noise performance. It is understood, informally, that its unweighted signal-to-noise ratio is of the order of 34 db. Weighted, and with synchronizing pulse, the figure would become 40 db.

No data are given in this literature on the signal-to-noise ratio of the 5826 image orthicon (same size of photocathode image as others), but it is understood, informally, to be of the order of 37 or 38 db. Weighted, and with synchronizing pulse, this becomes 43 db.

It has been noted above, in the presentation of Fig. 1, that the dotted lines refer to the data as taken. In the tests the slide was scanned by a special test scanner, revised from a prewar scanner.[10] From general experience with this scanner, it is considered to have low though visible noise. By the addition of a constant noise, on an rss basis, to that indicated by the dotted lines, they can be straightened out, as shown by the solid lines, and it is estimated that this constant noise measures the contribution of the film scanner. The figure is shown to be 46 db signal-to-weighted noise (including synchronizing signal). If the distribution were flat, the unweighted figure, for the 4-mc band, would be 43 + db.

6. Appendix

For simple reference the results of computations of two sharp cutoff and two sloping cutoff distributions, with the

weightings shown in Fig. 2, are given in Table III.

References

1. P. Mertz, "Perception of television random noise," *Jour. SMPTE*, vol. 54, pp. 8–34, Jan. 1950.
2. M. Luckiesh and F. K. Moss, "The variation in visual acuity with fixation-distance," *J. Optical Soc. Am.*, vol. 31, pp. 594–595, Sept. 1941; *The Science of Seeing*, Van Nostrand, New York, 1937; "The dependency of visual acuity upon stimulus distance," *J. Optical Soc. Am.*, vol. 23, pp. 25–29, Jan. 1933.
   E. Freeman, "Anomalies of visual acuity in relation to stimulus-distance," *J. Optical Soc. Am.*, vol. 22, pp. 285–292, May 1932.
3. P. Mertz, A. D. Fowler and H. N. Christopher, "Quality rating of television images," *Proc. Inst. Radio Engrs.*, vol. 38, pp. 1269–1283, Nov. 1950.
4. C. E. K. Mees, *The Theory of the Photographic Process*, Macmillan, New York, 1942.
5. O. H. Schade, "Electro-optical characteristics of television systems: Introduction," *RCA Rev.*, vol. 9, no. 1, pp. 5–13, Mar. 1948.
   "Part I—Characteristics of vision and visual systems," *ibid.*, pp. 13–37, Mar. 1948.
   "Part II—Electro-optical specifications for television systems," *ibid.*, no. 2, pp. 245–286, June 1948.
   "Part III—Electro-optical characteristics of camera systems," *ibid.*, no. 3, pp. 490–530, Sept. 1948.
   "Part IV—Correlation and evaluation of electro-optical characteristics of imaging systems," *ibid.*, no. 4, pp. 653–686, Dec. 1948.
   "Image gradation, graininess and sharpness in television and motion picture systems," Part I: Image structure and transfer characteristics," *Jour. SMPTE*, vol. 56, pp. 137–177, Feb. 1951.
6. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.
7. M. W. Baldwin, "Allocation standards for very high-frequency television and frequency modulation broadcasting," (Report of experiments of T. R. D. Collins, Annex 8) *Proc. Joint Technical Advisory Comm.*, vol. II, Dec. 1948. (This publication is available at The Joint Technical Advisory Committee, 1 East 79th St., New York 21.)
   E. W. Chapin and G. H. Brown, Exhibits 389 and 424, respectively, Dockets 8736, 8975, 9175 and 8976, "Record of FCC Hearing on Color and Allocations, 1950." (This publication is available at the Federal Communications Commission, Washington, D.C.)
8. L. A. Jones and G. C. Higgins, "Photographic granularity and graininess,
   "Part I—The relationship between the granularity and graininess of developed photographic materials," *J. Optical Soc. Am.*, vol. 35, pp. 435–457, July 1945.
   "Part II—The effects of variations in instrumental and analytical techniques," *ibid.*, vol. 36, pp. 203–227, Apr. 1946.
   "Part III—Some characteristics of the visual system of importance in the evaluation of graininess and granularity," *ibid.*, vol. 37, pp. 217–263, Apr. 1947.
   "Part IV—Visual acuity thresholds; dynamic versus static assumptions," *ibid.*, vol. 38, pp. 398–405, Apr. 1948.
   "Part V—A variable-magnification instrument for measuring graininess," *ibid.*, vol. 41, pp. 41–52, Jan. 1951.
   "Part VI—Performance characteristics of the variable-magnification graininess instrument," *ibid.*, vol. 41, pp. 64–75, Feb. 1951.
   "Part VII—A microphotometer for the measurement of granularity," *ibid.*, vol. 41, pp. 192–200, Mar. 1951.
9. R. B. Janes, R. E. Johnson and R. S. Moore, "Development and performance of television camera tubes," *RCA Rev.*, vol. 10, pp. 191–223, June 1949; R. B. Janes, R. E. Johnson and R. R. Handel, "A new image orthicon," *ibid.*, vol. 10, pp. 586–592, Dec. 1949.
10. A. G. Jensen, "Film scanner for use in television transmission tests," *Proc. Inst. Radio Engrs.*, vol. 29, pp. 243–249, May 1941.

Modified Negative Perforation

Proposed as a Single Standard for 35-Mm Negative and Positive Motion Picture Film

By W. G. HILL

The existence of two or more perforation shapes for 35-mm films has, for many years, been considered undesirable. For processes requiring accurate film positioning, the dual Standard of Negative perforation for camera stock and Positive perforation for release stock does not suffice. Registration problems are minimized if Negative perforations are used throughout; experience, however, has shown that projection life is short. The Modified Negative perforation, with fillets at the corners, has improved resistance to tear while preserving the general negative form corresponding to conventional piloting means. Tests conducted show that better film positioning is accomplished in conventional camera and printing equipment for film with Modified Negative perforations than for film with Dubray-Howell perforations. The method of evaluating film location during exposure and printing is described and evidence of results presented. Photoelectrically recorded charts show the extent of out-of-register which resulted for various combinations of perforation types. Film-life projection tests indicate that the Modified Negative perforation is equal or superior to the Dubray-Howell perforation.

THE PERFORATED HOLES in motion picture film provide a means whereby the continuous strip material can be propelled in synchronism with and in register to various machine components used in the production and reproduction of successive picture images. For the most part, sprocket wheels and pilot pins are used to engage the film perforations and effect positioning of the film strip. The former are most extensively used in printing and projection equipment whereas pilot-pin devices are more common in cameras and step printers where the advance of the film is intermittent and extreme accuracy is required. For many processes, such as in color film work, consistently accurate positioning of the film is of utmost importance. This is particularly true when more than one negative film is used to make up the master, and is desirable in all reproduction processes in order to preserve screen steadiness. The fit of the perforations on the registration sprocket teeth or pilot pins influences the degree of steadiness

A paper presented on May 2, 1951, at the Society's Convention in New York, by W. G. Hill, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y.

in the final release print and is, therefore, of vital concern to the motion picture industry.

The general form of the Standard Negative perforation, modified to the extent of incorporating slight fillets at the corners, is a shape of perforation worth considering as a single standard for 35-mm film. Experience with the negative form and tests conducted on film with the suggested modified perforations show this curved-end type of hole to be suitable for camera, dupe and release films. Image registration and picture steadiness, as produced with typical equipment, are improved when using the Modified Negative perforations noted above over that accomplished with the use of the present Negative and Positive combination or proposed rectangular Dubray-Howell perforation. Tearing of the film at the perforation during projection is less severe for the Modified Negative perforations than for the Dubray-Howell perforations tested. It appears that advantages gained by adopting the Modified Negative perforation as a single standard can be realized without the necessity of altering equipment.

Perforation Shape

Considerable information dealing primarily with the size and shape of the hole has been published on the standardization of perforations for 35-mm films. The history and reference to papers on the subject are well covered in a *Journal* report.[1] The proposal embodied in the report and presented for trial and comment specifies a rectangular perforation 0.110 in. × 0.073 in. with 0.013-in. corner fillets. This form of perforation was proposed by Dubray and Howell in 1932 and is usually referred to as the Dubray-Howell perforation. With recent acceptance of this perforation by some processing companies, we now face the problem of dealing with three types of perforations instead of two, which the industry has accepted as standards for many years. The Dubray-Howell perforation is substantially the same shape as the Standard Positive, but has a height of 0.073 in. instead of 0.078 in. and corner radii of 0.013 in. as against 0.020 in. for the Positive. The 0.073-in. dimension (same as for the Standard Negative perforation) is calculated to give no new difficulties in sprocket-tooth-to-film interferences. More important is the fact that there are advantages in the overall perforation size being the same for all camera, dupe and printing stocks. It is believed that with the new low-shrink safety film supports there is no valid reason to continue using the oversize Positive perforation. Experience has shown that the smaller perforations of like size and shape can be successfully used for all general types of 35-mm film. Since most commercial film-handling equipment, precision built to provide accurate registration, is designed to fit the Standard Negative perforation, Z22.34, it appears advisable to maintain the overall size therein specified for negative raw stock rather than the larger positive size.

The circular-end form, like the Negative standard which has been almost universally used since 1918, gained wide acceptance and is still used for work requiring accurate registration. Although efforts have been made in this country and Europe to standardize on the rectangular Positive perforation, and more recently in this country to standardize on the Dubray-Howell perforation, the round-ended perforation has, nevertheless, survived. Reluctance to accept the Dubray-Howell type of perforation as a single standard may be explained partially by the fact that new pins and sprockets to correspond are necessary in order to gain the most benefits in improved registration. In this connection, it should be noted that in the report of the Subcommittee on Perforation Standards, published in the *Journal*,[2] reference is made to proposed new pilot pins and sprocket teeth to fit the Dubray-Howell perforation for improved means of regis-

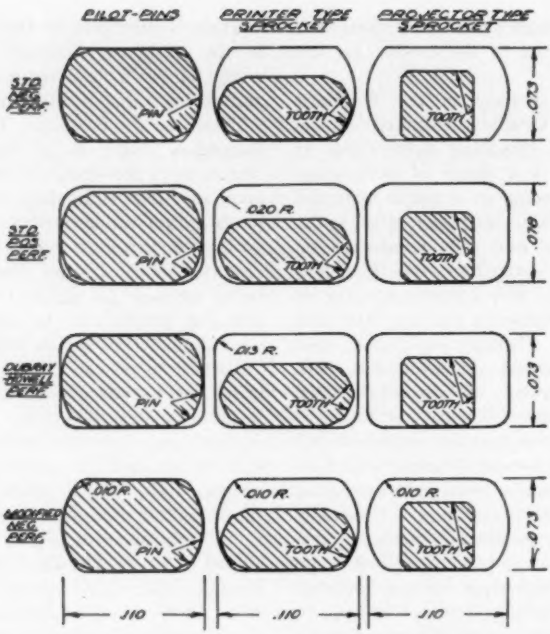


Fig. 1. Relationship of various perforations to pilot pins and sprocket teeth.

tration. In regard to printer sprockets, the report points out that, "...the recommended modification of printer sprocket design would be a marked improvement in the printing process, but would not be essential." Further, the report states, "It is to be noted, however, that locating on the unmodified printer sprocket two films having rectangular perforations requires some care." Stock films with Negative perforation could not, of course, be accommodated on rectangular teeth of the proposed modified sprocket. Because of such complications and additional expense of changeovers, the rectangular perforation form has not been accepted by the industry as the single standard for negative and positive films. The negative Bell & Howell perforation without corner fillets, although proven by experience to register accurately on existing equipment and provide adequate steadiness, is not ideally suited for projection films because of its low resistance to tear. The solution seems to be the establishment of a single universal perforation which will give good registrations on present piloting pins and sprockets and at the same time have sufficient strength so as not to limit projection life. Further, such a perforation should, when used for positive and negative film or in conjunction with "stock" film having Standard Negative perforations, register with the best possible accuracy without the necessity of altering equipment. The author believes that a modified form of the Standard Negative perforation, discussed in this paper, meets these requirements and makes possible the unlimited use of form-fitting sprockets for side guiding.

Figure 1 shows four types of perforations under consideration and the rela-

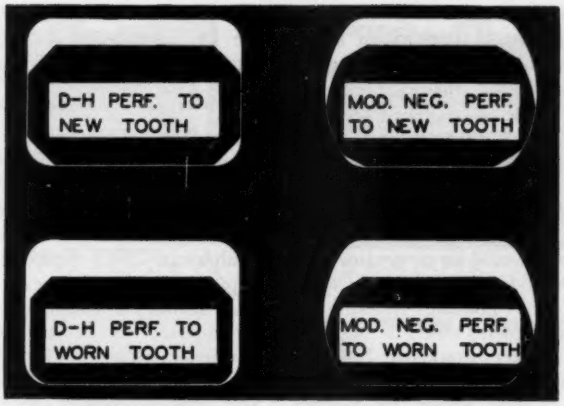


Fig. 2. Drawing showing side clearance between perforation and guiding sprocket.

tion each may assume with respect to commonly used pins and sprocket teeth. The curved-end form, Negative and Modified Negative, the latter differing from the Standard Negative only in the 0.010-in. fillet at the corners, are substantially full fitting with the pilot pins. In contrast to this, the rectangular Dubray-Howell and Positive perforations locate at the ends by point contact only. The Positive hole, being 0.005 in. higher than the pin thickness, does not, of course, fit along both long sides as do the other three holes. As for the relation with typical printer sprocket teeth, the round-ended forms locate sidewise at the driving tooth, whereas clearance exists at the short sides of the Dubray-Howell and Positive holes. In the case of the projector sprocket and those used where registration is not critical, the relation of perforation to tooth is similar for all types shown. The fit of perforations to the registering sprocket tooth as shown for printers suggests that the same tooth form could be used in projectors and related equipment where better steadiness is desirable. Note that the round-ended form of hole, with tooth to correspond, provides what appears to be a more reliable self-centering means. If wear on the sprocket tooth is considered, it is evident that the round-ended form is superior in that, as the face and the side of the tooth wear, the Negative form tends to wedge and center the perforation. The rectangular tooth, when worn, is not self-compensating and clearance at the sides will result. This is shown schematically in Fig. 2. Wear on the sides of the rectangular form results in clearance between tooth and perforation and destroys the ability of the tooth to register the film properly. A similar condition may result for pilot-pin registration. Guiding the film by full-fitting pins or teeth at one row of perforations is common practice where positioning of the film is critical. But where side motion need not be closely controlled, the teeth are narrower than the perforation width. In this case, shoulder edge guides are usually used and for such applications the perforation shape does not pose a problem. As for affecting accurate transverse registration by forcing the film against one side of the tooth, those familiar with film-handling equipment recognize the potential difficulties.

It appears evident, therefore, that the adoption of the suggested Modified Negative perforation should be given

consideration. Little, if any, reluctance to accepting such a perforation is expected if field trials bear out our finding as determined by factory tests. A single-perforation type would permit reduction of tool expense and inventories for the film manufacturers, and would permit greater flexibility in machine usage. The expense of changing to the specific Modified Negative form suggested would be no greater than for the Dubray-Howell. In fact, when considering the possible necessity of changing equipment which is now designed to register Standard Negative perforations, the expense for the change to Dubray-Howell would be greater. For the studio and laboratory, no extra expense or new problems should arise by the acceptance of the Modified Negative perforation. There would be no need to provide two types of pins or heads. With all new films supplied with Modified Negative perforations, the registration problem, particularly if stock negatives must be used, is simplified. For the film distributors and theaters, the Modified Negative perforation should give sufficient resistance to tear at the perforation area. Indications are that the Modified Negative hole weakens the film less than the Standard Negative and is equal to or better than the Dubray-Howell.

Briefly, the Modified Negative type of perforation has several advantages over the Dubray-Howell form. The most outstanding, perhaps, is the improvement gained in registration on standard continuous printers which are used extensively for making final release prints. Also important is the fact that existing perforated film could be run on any equipment made to conform specifically to the Modified Negative perforation.

The discussion to follow describes actual tests with camera and printing films having various types of perforations. The method of evaluating "unsteadiness" is indicated and evidence of the results presented in the form of recorded charts. Tear studies comparing the Dubray-Howell and the Modified Negative perforation are also described.

Test Method—Film Registration

The term registration, when used in connection with motion picture-making processes, generally implies the positioning of one film with respect to others or with respect to some fixed part of the equipment. Film exposed in the camera is piloted by pins engaging the perforations so that the film is oriented similarly for each successive frame and accurately positioned. Print registration is accomplished by piloting the picture negative and the duplicating stock accurately frame by frame or perforation by perforation, so the image transfer is "in-register." Any out-of-register contributes to picture unsteadiness and, for processes requiring multiple exposures, causes poor image definition.

The perforated holes are punched in the film by tools made to extremely close tolerances. These holes serve as a reference point to which image position is gaged. The degree of improper registration and variations in film positioning, therefore, can be determined by measuring the distances from the perforations to a point in the photographic image. The process of frame-by-frame measuring of these distances under the microscope is laborious and, consequently, is usually limited to comparatively short samples. To check the practical significance of such findings, it is desirable to examine longer lengths of film and correlate the data with results as found by a jury viewing the projected picture. The method of evaluating steadiness used by Ansco in the studies described here permits visual examination of the projected image and, at the same time, records the extent of image shift attributed to improper piloting of the film at the time of exposure. Long lengths of film can thereby be tested and data obtained without the need of the time-consuming frame-by-frame measurements. The sys-

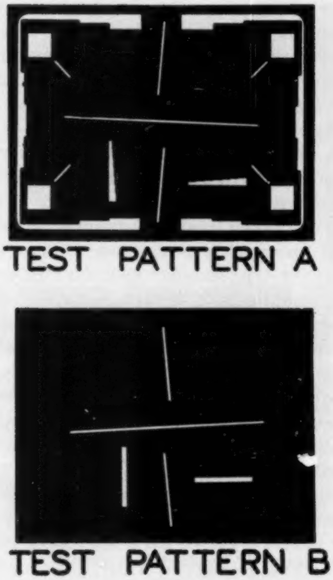


Fig. 3. Target patterns.

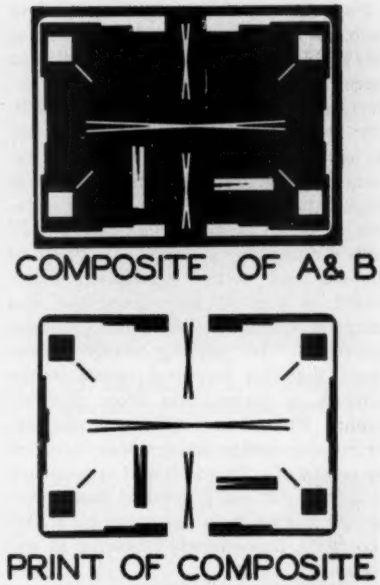


Fig. 4. Composite of target patterns.

tem of using double-exposed images to indicate out-of-register, which is familiar to some, was selected not only to enable convenient viewing by projection but also to permit the use of a single-channel recording device.

Two "targets," illustrated in Fig. 3, were provided in order that exposure, first to one and then to the other, would result in cross-line patterns and also form "light slits," the sizes of which vary depending on the differences in positioning of the film during the first and second exposure. The crossover lines, forming tapered wedges, are used primarily for visual studies of the projected image, whereas the stepped slits are arranged conveniently for photoelectric recording of the vertical and horizontal variations. Figure 4 represents the composite formed by superimposing image of target A and target B, shown in Fig. 3. The size of the original target was selected so as to give successive step distances of 0.002 in. on the wedge image formed on the camera film. This provided a means of visual checking of the approximate variations in "slit" width on the printed film during projection. The system of superimposing images described is applicable not only to testing registration ability of equipment for a particular film, but valuable, as in this case, in evaluating different films or types of perforation holes on given equipment. In the latter case, the same camera, printer and related apparatus were used for all comparison tests, thereby eliminating variables in equipment. It is well to point out that in testing for registration, by the method of superimposing films, the maximum shift of the first to second images may be twice that for either image separately. This total shift of one with respect to the other, however, is what may be encountered in actual picture making and consequently is indicative of the true situation.

For purposes of investigation, 300 ft of each test film were exposed in a camera; 100 ft to target A; the second 100 ft to target B; and the third 100 ft, consecutively superimposed to targets A and B. The latter, composite negative of A and B, was used to check registration in the camera. For the print tests, a 100-ft dupe film was printed from camera negative of target A and then "in-register" with the negative of target B. Prints of the resulting picture composites (illustrated in Fig. 4) were projected and image registration of the various samples compared. In judging image movement, that due to out-of-register in the camera, of course, was taken into account. Picture unsteadiness of the projected step-wedge images was recorded by means of a photocell and appropriate electrical circuits, a detailed description of which is given in the paper by R. W. Lavender, immediately following in this JOURNAL.

Test Apparatus and Equipment

Photographic apparatus used in the testing program was standard commercial equipment, typical of that in general use by the trade. No attempt was made to replace critical parts of the equipment which might have been worn by normal use. On the contrary, equipment used for routine trials was selected as being equivalent to that in operation in many studios and laboratories. Pilot pins and registering sprockets were the Standard Negative type. Most of the trials were made at the Ansco factory; however, some runs were conducted at other plants. Although it is recognized that the introduction of a new perforation standard would affect operations on a number of different machines including special-effects projectors, splicers, recorders, etc., it was deemed sufficient to limit the tests to typical cameras, continuous printers, step-optical printers and theater projectors. Film advance and registration mechanisms contained in such units represent, in general, the types of movements universally used. Therefore, evaluation of steadiness and performance for the test described here was limited to trials on the four types of equipment noted.

A Mitchell camera having synchronous motor drive and Standard Negative pulldown and pilot pins was used. The Bell & Howell model continuous printer, used for making evaluation prints, had Negative-type sprocket teeth for effecting side guiding of Standard Negative perforations. Step-optical prints were run on an Acme-Dunn unit which is maintained by our Motion Picture Development Department for testing purposes. Projection runs were made on a Super Simplex with a 0.935-in. diam, 16-tooth, intermittent sprocket. The 50-amp arc light was used during wear and tear tests. For steadiness evaluation trials, however, the light was converted to a 2100-w, 60-v incandescent lamp. This light source provided constant illumination which is essential to the system used for recording.

Figures 5A, 5B and 5C show the test screen and equipment setup for recording steadiness data. View 5A is of the projection side of the screen on which is mounted two photocells and the calibrating unit. The photocells are arranged so the projected image of the step-wedge formed on the film by the double-exposed target pattern falls on the light-sensitive cell element. View 5B is of the calibrating device. This is simply a d-c motor which drives an eccentric bushing mounted to form a rectangular window with a second bushing and the top and bottom of the opening in the cell housing. Both bushings are made to push-fit over the shafts in order that different diameters and eccentrics may be used to vary the slot width. Figure 5C shows the amplifier and recording equipment mounted at the rear of the screen. The test screen was positioned so as to give a 50× enlargement of the projected image at the screen.

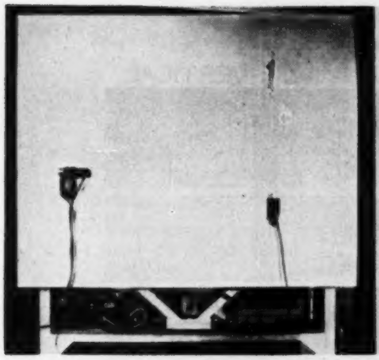


Fig. 5A. Test screen from projector side, showing photocell holders and calibrating unit.

Fig. 5B. Close-up of calibrating unit mounted in front of photocell.

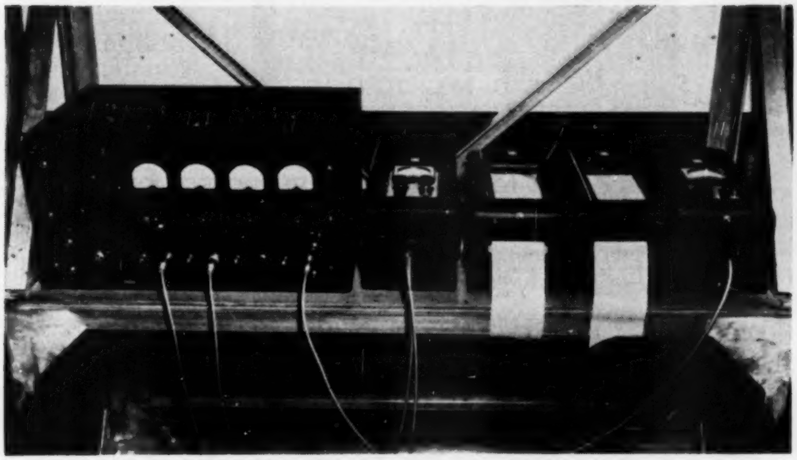


Fig. 5C. Electronic units and recorder mounted at rear of screen.

Registration Studies

Each test series, including samples of various perforations under consideration, was conducted on material from the same film coating and, where possible, was selected from the same 35-mm roll. For the most part, testing was limited to safety base materials typical of those now used in motion picture work. Some steadiness checks, however, were made on nitrate base but no attempt was made to draw comparisons between performance of the two materials. Dubray-Howell and Modified Negative tools, used in perforating the sample films for test X, were made to like tolerances and selected to give comparable hole sizes. All runs in a given series were made consecutively under similar conditions so as to eliminate variables which might reflect

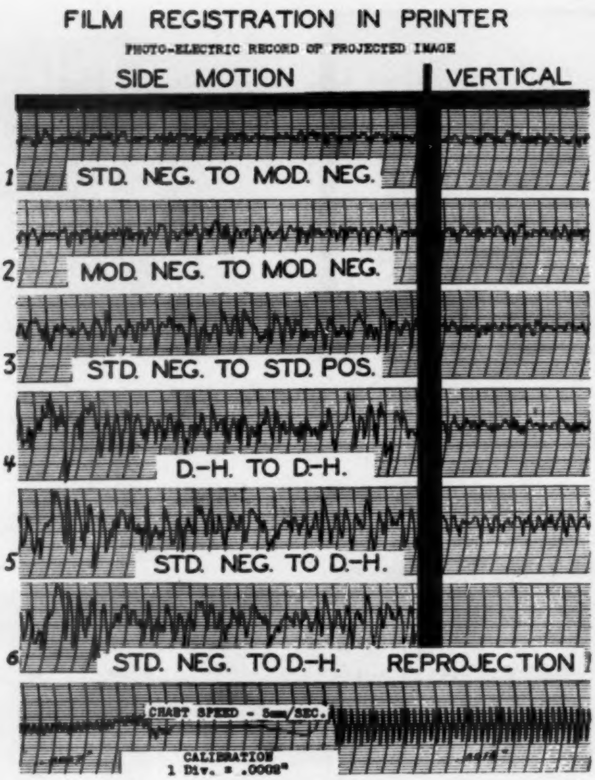


Fig. 6. Charts—Test X on sprocket printer.

in the data and thereby render the comparisons questionable.

The steadiness or degree of film registration accomplished on a Bell & Howell continuous printer, test X, is indicated in Fig. 6. These charts are the results of photoelectrical detection of the relative shift of first- and second-exposure images as observed during projection of the printed test film. The pattern, forming light slits at which the variations were measured, was the result of printing the negative of target A to the positive film and then printing the negative of target B to the same positive film. Therefore, variations or out-of-register shown are those due to nonuniform positioning of the films on the printing sprocket and inaccuracies in the original negatives. The latter are comparatively small as will be shown later in Fig. 8. Film having Standard Negative perforations was double printed to films with Modified Negative, Standard Positive and Dubray-Howell perforation. The recorded out-of-register results are shown by charts 1, 3 and 5 of Fig. 6. In the case of chart 1, Standard Negative to Modified Negative, the average side motion was approximately 0.0007 in. For chart 3, to Standard Positive, the variation is in the order of 3 times that

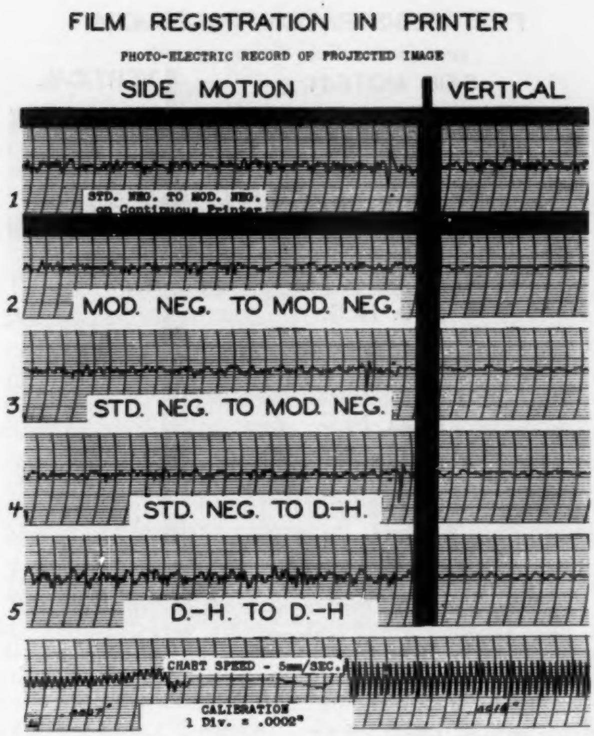


Fig. 7. Charts—Test X on optical printer.

for chart 1, and for chart 5, to Dubray-Howell, about 4 times. The results of printing camera negatives, having Modified Negative holes, to films with the same type of perforations, and negatives with Dubray-Howell holes to like film, are shown by charts 2 and 4, Fig. 6. Variations for the Modified Negative perforation appear to be distinctly less than for the Dubray-Howell combination. In order to verify the accuracy of recording out-of-register, the test print was reprojected and the results compared with the previous run. One section of the chart thus obtained is shown in curve 6 of Fig. 6. In comparing this with curve 5, it will be noted that the duplication is near perfect. Vertical motion between the first and second printed images shown at the right of Fig. 6 appears to be comparable for all samples (about 0.0010 in.). The calibration chart at the bottom of Fig. 6 was obtained by projecting the clear area of the test film through the controlled variable calibrating slot and onto the photocell. Knowing the magnification and slot-width change at the cell, the gain of the unit was set so that each small division on the chart represented approximately 0.0002 in. at the film. With the slot area fixed, and the cell receiving light through the clear film area, no movement of the recorder pen could be detected; thus indicating that the variations in light intensity and film density were negligible.

The same camera negatives used for the continuous printer test described

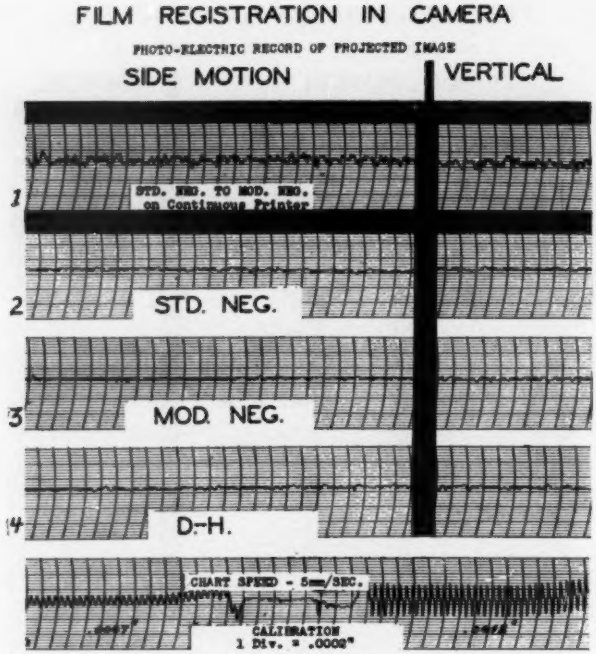


Fig. 8. Charts—Test X on intermittent camera.

above were also used for testing out-of-register on a step-optical printer. Using the same general method as before, the charts shown in Fig. 7 were recorded. Charts 2, 3 and 4 for Negative-type perforations on originals to Negative and Dubray-Howell types are comparable, indicating side motion of from 0.0006 to 0.0008 in. These also show side motion to be in the same order of magnitude as on chart 1 for the continuous print sample of Standard Negative to Modified Negative perforations. The print of Dubray-Howell to Dubray-Howell, chart 5, shows greater side movement, from 0.0010 to 0.0012 in. Vertical motion for all step-optical prints was about the same (0.0004 in.). The degree of vertical unsteadiness in these instances was much better than for the continuous prints and only slightly worse than for the camera test.

Charts 2, 3 and 4 in Fig. 8 are records of variations attributed to inaccuracies in positioning of the film in the camera. All samples show from 0.0003-in. to 0.0004-in. variations in the horizontal and vertical direction. Chart 1 (Standard Negative to Modified Negative) of the continuous print sample of least variation (0.0007 in. avg.) serves as a comparison to the camera registration performance curves.

Test Y, Fig. 9, charts 1, 2 and 3 are taken from a different series of camera and print film tests. The negative, which was perforated with tools converted from Standard Negative to Modified Negative type, was exposed by Ansco to test targets as previously described, but the printing was done by a commercial laboratory. These trials served not only to verify earlier observations but to check the degree of correct registration

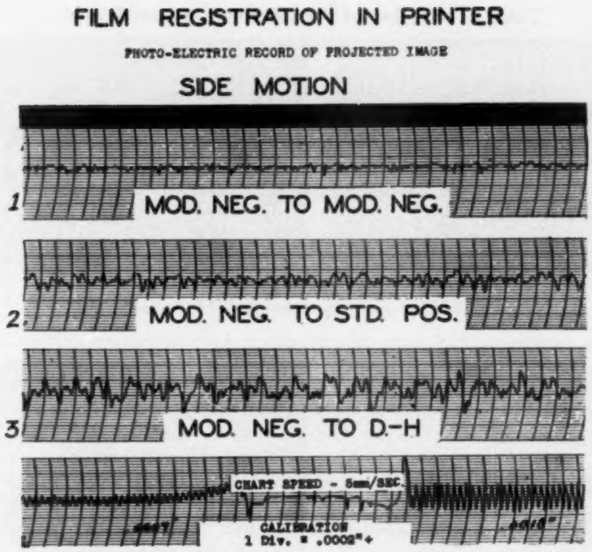


Fig. 9. Charts—Test Y on sprocket printer.

which might be expected when printing from the new Modified Negative perforated stock onto stock with the same perforations and also onto release or dupe film with Positive or Dubray-Howell perforations. The results of this laboratory test show the Modified to Modified to be best, variations being in the order of 0.0006 in. For the Modified to Dubray-Howell, however, variations were about three times greater. It will be noted that the calibration amplitude shown by the lower chart in Fig. 9 is slightly less than for the other figures, the smallest scale division equaling 0.0002 in. plus, or a little greater than for the other figures. This change may be accounted for by difference in density of the film used for the two series.

In reviewing steadiness tests conducted at Ansco over a period of several months, it is evident that in each case, the curved-end style of Negative or Modified Negative perforation is superior. This form of perforation hole gave the best steadiness when used for both the camera and print films. Negatives printed to film with rectangular perforation were not as good; however, they were distinctly better than for the Dubray-Howell type perforated camera material printed on Dubray-Howell perforated release stock. Our findings substantiate the theory that improved pin registration and sprocket guiding will result on commonly used commercial equipment if film with curved-end perforation is used throughout.

Perforation Wear and Tear Resistance

Film samples for wear tests were made up in 40-ft loops. Although some trials were made on loops containing only one type of perforation, the data presented here is a comparison of two types of holes in the same film strip. Both tests reported here were on safety film, developed clear and projected on the same machine. Films for wear tests were not waxed or otherwise conditioned to improve projection life as is usually done commercially. In preparing film strips,

Table I. Number of Torn Perforations per Frame

Film D-145-1: Loop 1			Film D-145-2: Loop 2		
No. of Projections	Mod. Neg. Perf.	D-H Perf.	No. of Projections	Mod. Neg. Perf.	D-H Perf.
202	2(slight)	3(slight)	220	0	1(1 slight)
396	2(1 slight)	4(2 slight)	321	0	1
508	3	5(1 severe)	715	3(2 slight)	2(1 slight)
671	3	5	974	3	5
892	3	5	1154	3	6(4 slight)
1198	3	6	1271	3	6(2 slight)
1273	5	6(4 severe)	1628	6(1 slight)	6(4 severe)
			1819	6(3 severe)	6
			1914	6	6

half of each length was perforated on a machine with Dubray-Howell type tools and without cutting the sample, the second half was perforated on a machine with Modified Negative type tools. Films were ink-frame marked for convenience in identifying perforation during the projection run. While wear tests were in progress, observations of the projected perforation area were made and the condition of tearing around the perforations noted.

Film loops were run on a Super Simplex projector No. 41180, with 50-amp arc light and equipped with a 16-tooth, 0.935-in. diameter intermittent sprocket. Table I shows the observed results of these projection wear and tear tests on two different types of safety base film.

These and similar tests indicate that,

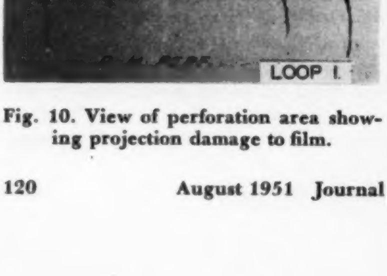


Fig. 10. View of perforation area showing projection damage to film.

under normal projection conditions, the Modified Negative form of perforation weakens the film less than does the Dubray-Howell form.

A study of the types of failure appearing at the perforation area revealed a distinct difference in the cracks which were produced during the projection runs. Figure 10 shows views of the perforation area along one side of the Modified Negative and Dubray-Howell perforated samples taken at the completion of the wear test. It will be noted that for the Dubray-Howell type the crack is sharp and progresses transversely. The tear at the corners of the Modified Negative hole is broad and more in a line forming an angle with the straight side of the hole, that is, more lengthwise of the film. These breaks at the corners of the Modified Negative do not extend into the aperture area or to the film edge, as do some of the breaks in the sample perforated with Dubray-Howell holes. Figure 11 shows enlarged photographs of perforation area from loops 1 and 2 after completion of wear test runs. Damage to the Dubray-Howell perforated sample appears to be more severe. In tests conducted for the purpose of comparing the Standard Negative with Modified and Dubray-Howell perforations, the pattern of cracks was similar to that shown in Fig. 10. Although many of the cracks on the Standard Negative perforated film were

Loop 1. Film through projector 1273 times.

Loop 2. Film through projector 1914 times.

Fig. 11. Photographs of Dubray-Howell and Modified Negative perforations at completion of projection wear test.

Fig. 12. Photographs of strain pattern produced by 650-g load on perforation edge.

like those shown for the Modified Negative, some cracks extended transversley much like those on the Dubray-Howell perforated sample. These long fractures which apparently progress across the film with repeated loading seem to account for the more rapid breakdown.

In an attempt to determine why the two different styles of perforations cause film under load to break differently, as shown in Fig. 11, strain pattern studies were made. Clear safety-base film samples, 0.009 in. thick, were supported at the perforation edge on a pin 0.070 in. wide with 0.010-in. corner radii and loads of increasing amounts applied to the film. By means of polarized light, strain patterns were observed. Photographs of such patterns are shown in Fig. 12. Strain areas, indicated by light sections, are more sharply defined for the Dubray-Howell type hole, the areas of strain to no strain for the Modified Negative being blended more gradually. The strain area for the Modified Negative sample extends from the corner along the curved end for some distance and then gradually falls off; whereas for the Dubray-Howell shape, the strain disappears rather sharply and is not distributed as evenly along the short side. This, it is believed, explains why the break at the corner of the rectangular hole progresses across the film and is more extensive.

Conclusions

The curved-end style of the Standard Negative perforation, now almost exclusively used for camera films, registered more accurately in the camera, step-optical printer and continuous printer than did the rectangular form of Dubray-Howell or Standard Positive perforations. The Modified Negative perforation with 0.010-in. corner radii compared favorably to the Standard Negative perforation in registration and steadiness performance, reduced the tendency of the film to tear, and caused no apparent interference with piloting pins or sprocket teeth. Film with the Modified Negative form of hole can be used without limitation on equipment designed to run the present ASA Standard Negative and Positive perforation types and will position accurately on their registering mechanisms. Image steadiness of release prints, exposed on the Bell & Howell type continuous printer, is improved by using the Modified Negative perforation throughout.

We believe the consensus favors a single standard and that the complex situation due to the existence of multiple standards should not be permitted to continue indefinitely. On the basis of theoretical considerations and tests conducted on the Modified Negative perforation, the adoption of such a perforation seems to be a practical solution and a step toward the establishment of a single standard.

Acknowledgment

The problem of judging relative performance of films with different-shape perforation holes is a delicate one. Through the efforts of several people, much information, which is invaluable in determining a satisfactory solution, has been made available. The SMPTE Film Dimensions Committee under the chairmanship of Dr. E. K. Carver has played an important part in encouraging such investigations as might lead to a final settlement and perhaps to the establishment of a single universal perforation standard. The author wishes to acknowledge the work of Carl L. Schaefer on the steadiness problem and his cosponsoring of the Modified Negative perforation as a possible universal standard. The photoelectronic recorder was developed by Raymond W. Lavender.

References

1. Proposed American Standard, *Jour. SMPE,* vol. 52, pp. 447–452, Apr. 1949.
2. Report of the Subcommittee on Perforation Standards. *Jour. SMPE.* vol. 29, pp. 376–387, Oct. 1937.

Discussion

L. L. Ryder: How do you distinguish between lack of registration from perforation deficiencies and the other factors that contribute to lack of registration?

Mr. Lavender: The method described, will distinguish only steadiness components relative to the screen or relative to the perforations. Whether unsteadiness is due to perforation defects or design, or whether it is due to something within the projector, the camera or the printer, is something which has to be determined by other means.

Mr. Ryder: The data was used to determine the more essential system of perforating. Could that not also be partly attributed to the care of perforating, or the accuracy of perforating, rather than the type of perforation?

Mr. Hill: There is no question that the accuracy of perforating definitely has a bearing on results. We were primarily comparing one film with another, and therefore in perforating these films we took care to see that the tools and machines were as nearly alike as possible. The punches and pilots were made to the same tolerances and, therefore, we feel that it is a fair comparison of types of perforation. I might add that you could locate photocells at various positions, perhaps on two successive perforations, or at the first and third on a frame, and, by the method Mr. Lavender has explained, get variations in perforation pitch and alignment.

Photoelectronic Method for Evaluating Steadiness of Motion Picture Film Images

By R. W. LAVENDER

Comparative data on the steadiness of motion picture film images are generally obtained by recording the qualitative observations of viewers. Recent problems encountered in evaluating the relative merits of several types of perforations, each of which was being considered as a universal 35-mm standard, necessitated the development of a method for obtaining specific quantitative steadiness data. An instrument which utilizes variable-area photoelectric recording techniques was devised to measure, indicate and record steadiness data of the motion picture image relative to the screen and/or perforation. Use of this instrument and a special test screen permits viewing of a projected motion picture test film while simultaneously measuring the image steadiness and recording the data measured.

The steadiness of a motion picture depends on the accuracy with which successive projected picture frames occupy the same position on the viewing screen. The positional variations of the frame image relative to the screen can be completely defined in terms of any one or combination of the following:

(a) longitudinal position variation, Fig. 1a;

(b) transverse position variation, Fig. 1b; and

(c) rotational position variation, Fig. 1c.

Although steadiness, as defined above, is a quantitative measurement of the positional variation of the motion picture frame image relative to the viewing screen, it is the subjective or apparent steadiness which is generally of primary importance. Thus, the present visual test method of evaluating steadiness by jury opinion is fundamental. Nevertheless, specific quantitative data are frequently desired for the purpose of more accurately determining the magnitude, frequency, and source or sources of unsteadiness. For example, recently it was considered desirable to obtain quantitative steadiness data of film which had been perforated with several different types of perforations, namely, the Dubray-Howell, the Standard Negative and the Modified Negative—the latter proposed by W. G. Hill and C. L. Schaefer of Ansco. Each of the foregoing perforations was being considered as a universal 35-mm standard.

In an effort to obtain basic comparative data on the relative steadiness of the above perforations, the photoelectronic recorder described herein was developed.

Presented on May 2, 1951, at the Society's Convention at New York, by R. W. Lavender, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y.

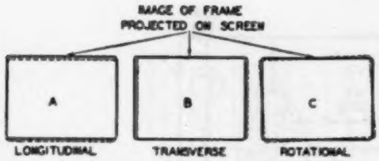


Fig. 1. Steadiness components of motion picture frame image.

The results of tests conducted with this instrument relative to perforation steadiness plus others are described in W. G. Hill's paper, "Modified Negative Perforations Proposed as a Single Standard for 35-Mm Motion Picture Film" (the paper immediately preceding in this JOURNAL).

The subject recorder, in addition to being of some value as an adjunct to the visual test method of steadiness evaluation, has a further usefulness in that it can provide recorded data which will indicate the amount of unsteadiness contributed by the camera and printer and/or projector. Further, these data are obtained concurrently with the visual inspection. If desired, the observer of the projected image on the screen may operate switches which will cause identifying marking "pips" to be made on the recorded chart for reference purposes.

The instrument is basically a variable-area photoelectronic recorder in which movement of the projected frame or image, relative to the viewing screen, results in a change in the total light flux falling on one or more photocells. This is illustrated in Fig. 2, which shows the photocells mounted on the test screen on which is projected an image of the film including the perforations—the gate of the projector having been opened to permit the projection of the full film width. Note that a longitudinal displacement of the picture frame, frame image and perforation image, results in a vertical movement of the position of the boundary line between the cross-hatched and clear areas relative to the photocells.

If the following assumptions are made:

(a) the cross-hatched area, Fig. 2, is opaque and the clear area transparent;

(b) the light intensity is constant and is uniformly distributed over the photocell window area; and

(c) the sensitivity of the cathode surface of the photocell is approximately constant over the area chosen;

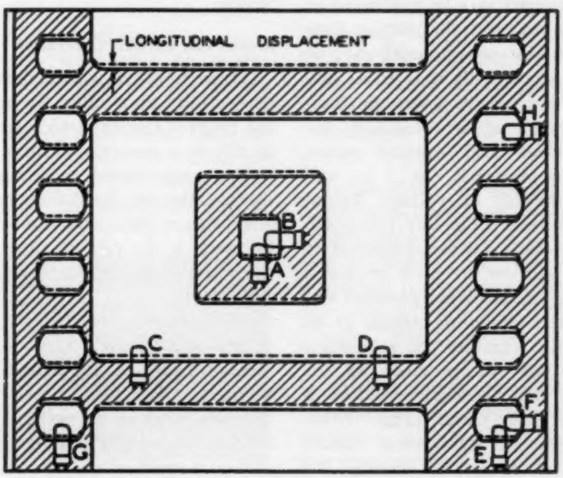


Fig. 2. Positions of photocells on test screen.

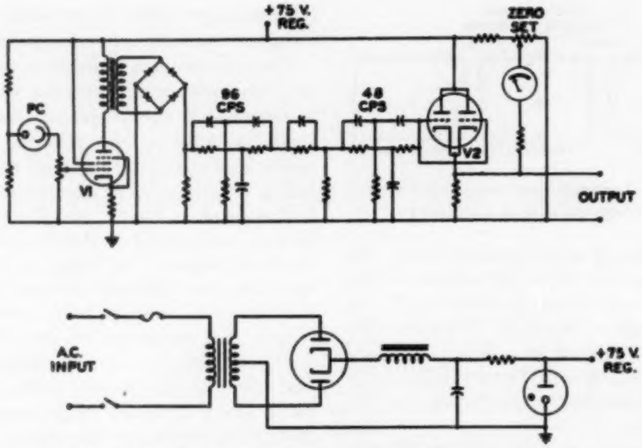


Fig. 3. Photocell demodulator channel—elementary.

then the position variations of the boundary between the cross-hatched and clear areas relative to the photocell windows will result in proportional changes in photocell output current.

It is desirable and necessary that the constant of proportionality, for boundary position variations to output current or voltage change, should have the same value for each photocell. When this is the case, the output may be calibrated in terms of position, and the output data obtained from any one photocell may be directly compared with that from any other. In other words, a specific position displacement of the boundary between the clear and opaque areas, parallel to any photocell, e.g., 1 in., will result in a current or voltage output change of one volt from any photocell. The above is practically accomplished by making the window in each photocell enclosure, Fig. 5, the same physical size and shape, and providing means in an external circuit whereby the maximum photocell output voltage may be adjusted when the photocell window is fully within the clear area. More specific details on the actual circuit adjustments necessary to satisfy the assumed conditions are given under the heading *Instrument Adjustment and Operation*, below.

In the practical application of the proposed photoelectronic method for steadiness evaluation, it is, of course, necessary to filter out the steady-state frequency generated by the shutter in the projector and to replace the carbon arc with a voltage-stabilized incandescent lamp to obtain the required constant light intensity.

Electronic Circuit Operation

Those familiar with electronic circuit design fully appreciate the many different types of circuits which could be used to obtain a recorded output voltage directly proportional to image displacement under the conditions noted above. Although considerable improvement can be made in the circuit, shown in Fig. 3, the results obtained with it were quite satisfactory.

The operation of the circuit is briefly as follows:

A fraction of the photocell output voltage, developed across the gain potentiometer in the control grid circuit of the pentode, V_1, is amplified by V_1 and to a small extent by the transformer in its anode circuit. The secondary of

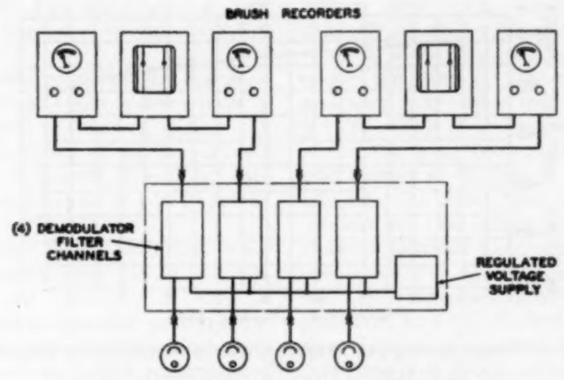


Fig. 4. Photoelectric steadiness evaluator for motion picture film images—block diagram.

this transformer is connected to a full-wave germanium diode bridge rectifier from which is obtained a d-c voltage proportional to the intensity of the pulsating light falling on the photocell. The twin "T" null-type filters, connected in cascade, effectively remove the steady-state ripple frequency components from the rectified d-c voltage. The output from the above filter circuit is connected to the grid of V_2. This tube, connected as a cathode follower, is used principally as an impedance transformer.

The low source impedance, characteristic of cathode followers, permits the use of a voltmeter as an output indicator and provides a convenient means for the mixing of outputs from different photocell channels. Thus, the recorders which are shown in the block diagram, Fig. 4, may be connected directly, as indicated, to the output from the demodulator filter channels or, if desired, the outputs from the channels may be combined to obtain relative steadiness data. For example, the change in the output voltage from the channel supplied by photocell A, Fig. 2, due to longitudinal position variations of the image boundary, may be combined with the output voltage from the channel supplied by photocell E and the difference or unbalanced voltage recorded. The voltage variations so obtained would be a measure of the motion of the film image relative to the perforation and would be indicative of the unsteadiness contributed by the camera and/or printer.

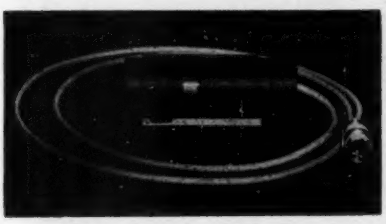


Fig. 5. Photocell housing; window ½ in. wide.

To facilitate the mixing of the photocell demodulator channel outputs, two of them supply a positive output potential with increasing light, whereas that of the remaining two supplies a negative potential. Aside from this output polarity reversal, the channels are electrically identical.

A frequency-characteristic curve of the channel gain as a function of modulation frequency is shown in Fig. 6. Ideally, this response should be flat from approximately ½ to 10 cycles/sec.

A photograph of the steadiness evalu-

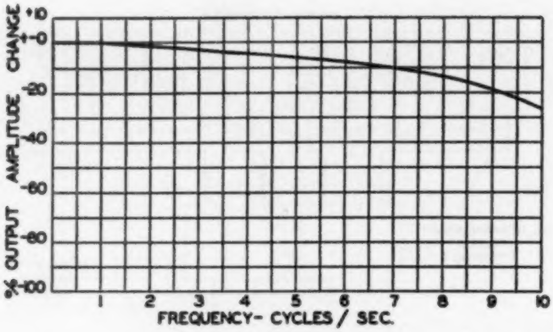


Fig. 6. Frequency-output characteristics of demodulator channel.

ator console and one of the console with the Brush Recorders mounted on a shelf in the back of the projection test screen are shown in Figs. 7 and 8, respectively.

Instrument Adjustment and Operation

The accuracy of the photoelectronic method for evaluating steadiness is contingent upon the conditions listed below:

1. The intensity of the projector light source during the test should be constant.

2. The light flux distribution on the viewing screen, in the absence of film, should be uniform over the photocell window positions.

3. The projector shutter speed should be constant; and if the null-type filters are used, these filters should be adjusted for the specific frequency generated by the shutter and the twice frequency ripple component resulting from the full-wave rectification of the amplified photoelectric a-c voltage.

4. The windows or openings in the photocell enclosures, Fig. 5, should be square or rectangular and each should have the same physical size and orientation relative to the photocell.

5. The light sensitivity of the cathode surface of the photocell over the window area should be constant.

6. The output voltage from each of the photocell channels should be adjusted to give the same value when the

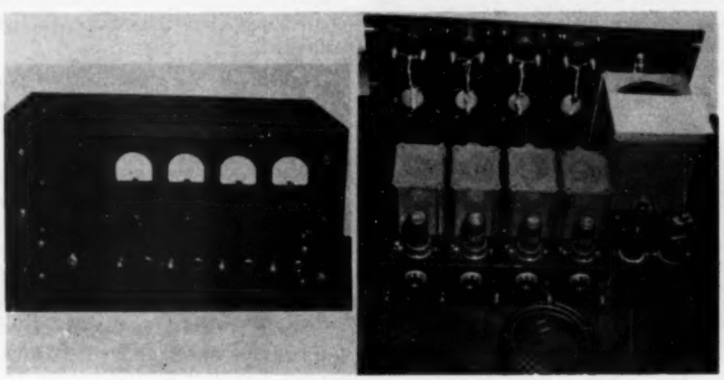


Fig. 7. Steadiness evaluator console.

photocells are fully illuminated at their respective positions on the viewing screen.

7. The differences in the sharpness between the clear and opaque areas of the film should be relatively small.

8. The recorded voltage output, as a function of frequency, should be constant from approximately $\frac{1}{2}$ to 10 cycles/sec.

9. The film density variations in the clear and opaque areas should be small.

The practical operation and application of this instrument for evaluating steadiness will be readily understood if we consider, in somewhat more detail, the adjustment of the instrument for recording the longitudinal component of steadiness. Consider again Fig. 2. In this illustration, the photocell housings have been removed for convenient representation. In actual use, the average position of the boundary between the cross-hatched and clear areas approximately bisects the windows of the enclosures. As previously stated, it is essential that the change in the output voltage from each of the photocell channels should be the same when the windows of the photocells are, first, fully within the clear portion of the image, and, then fully within the cross-hatched portion. This is conveniently done by setting the gain potentiometers in the grid circuits of V_1, Fig. 3, to zero and adjusting the meter-"zero set" potentiometers until the output meter in each channel indicates zero volts. The picture image, Fig. 2, is then framed downward, fully illuminating the windows of photocells A, C, D, G and E. Having done this, the gain potentiometers in the grid circuits of V_1 are adjusted until the output meters read midscale or one volt.

The film image is then framed upward so that the cross-hatched portion of the image fully covers the windows of the photocells and the output meter readings are noted. If the meter readings are other than zero, it indicates that some light is being transmitted through the cross-hatched portion of the film, which may require compensation. The compensation is accomplished by readjusting the meter-set potentiometers to obtain a

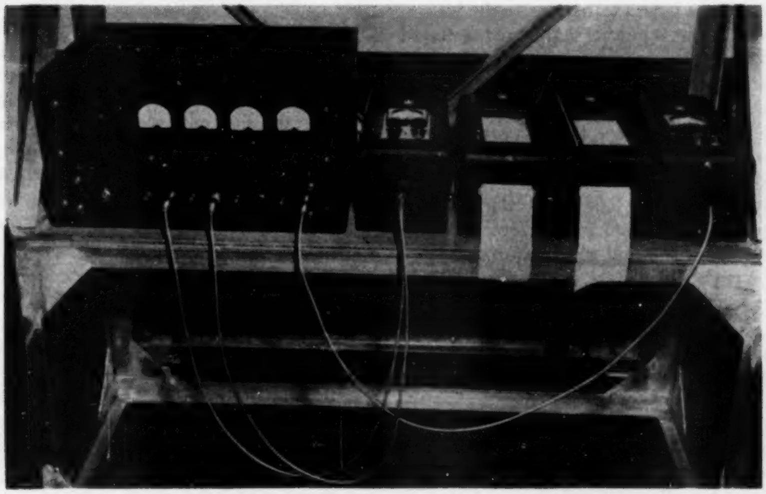


Fig. 8. Steadiness evaluator console and recorders back of test screen.

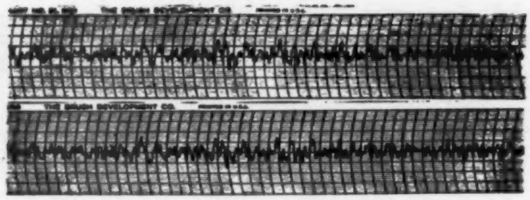


Fig. 9. Transverse position variations of frame image for two consecutive passes of test film through projector.

zero reading on the meters and framing the image of the film downward, until the photocell windows are again fully within the clear area. The gain potentiometers are then increased until the output meters read midscale or one volt. If, when the film image is again framed upward, the output meter readings are greater than approximately 0.1 v on any channel, the process is repeated. This is seldom necessary, however, for with reasonable care in preparing the film, the cross-hatched density is very high compared with that of the clear area and compensation is not required. The channels fed by photocells B, H and F are adjusted similarly by moving the test projection screen transverse to the image.

After the channel adjustments noted above have been made, the recorders are calibrated. In the tests conducted with the instrument, relative to the evaluation of the steadiness of the several perforation proposals previously referred to, the calibration was set for one small chart division for each 0.01-in. displacement of the image relative to the screen. This 0.01 in. was equal to an equivalent displacement of 0.0002 in. at the aperture on the projector.

The overall accuracy of the system is indicated in part by the similarity in the recorded chart patterns shown in Fig. 9. These curves represent the transverse positional variations between the image (photocell B), Fig. 2, and the perforation (photocell F) for two consecutive passes of the test film through the projector.

A few of the photocell combinations which may be used for obtaining specific steadiness components are listed below.

Steadiness Components of Frame Image Relative to Screen

1. Longitudinal Component—output from channel fed by photocell A;
2. Transverse Component — output from channel fed by photocell B; and
3. Rotational Component — unbalanced output from channels fed by photocell C and photocell D.

Steadiness Components of Frame Image Relative to Perforations

1. Longitudinal Component—unbalanced output between channel fed by photocell A and channels fed by photocell E and photocell G connected in parallel through suitable decoupling resistors; and
2. Transverse Component — unbalanced output between channel fed by photocell B and channels fed by photocell H and photocell F connected in parallel through suitable decoupling resistors.

The photoelectronic method of evaluating steadiness described herein has proven to be of value in supplying *recorded* qualitative and quantitative steadiness data. These *recorded* data are particularly useful in supplementing the information obtained by the visual inspection method of steadiness evaluation.

Sound Track on Eastman Color Print Film

By C. H. EVANS and J. F. FINKLE

The photographic image in the sound-track area of Eastman Color Print Film, Type 5381, is composed of metallic silver plus dye. The normal sensitometric specifications for sound negatives used in release printing on black-and-white materials are also suitable for negatives to be printed on Type 5381. The sound track should be printed by light which has been filtered in such a manner that the dye component of the developed image will be neutral. In general, the sound quality of neutral prints on Type 5381 is comparable with that of prints on Eastman Fine Grain Release Positive Film, Type 5302, but the latter has superior response at the higher frequencies.

EASTMAN COLOR PRINT FILM, Type 5381, is a 35-mm integral tripack three-color subtractive film, designed to be printed from picture negatives taken on Eastman Color Negative Film, Type 5247. In processing a release print on Type 5381, the initial stages are common to the picture and to the sound track. First, the images are developed to metallic silver plus dye. Next, the film passes through a fixing bath which removes all undeveloped silver halide, and then through a bleach which converts all silver to silver bromide. Following the bleach, the sound-track area alone is treated by application of a reducing agent. This converts the silver bromide of the sound track back into metallic silver. The reducer is washed from the film by a water jet, just before the film enters a wash tank. From that point on, picture and sound track again receive identical treatment. The resultant sound-track image is composed of both dye and metallic silver.

Communication No. 1402 from the Kodak Research Laboratories, a paper presented on May 4, 1951, at the Society's Convention in New York, by C. H. Evans and J. F. Finkle, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

Sound-Track Printing and Densitometry

In general, sound tracks on Type 5381 are printed from black-and-white negatives. There are two variables in the printing operation which can be used for controlling sound quality. One of these, the amount of exposure, controls the print density. The other, the color quality of the printing light, controls the shape of the H&D ($D - \log E$) curve pertaining to the sound track. The characteristic curve of each individual layer is determined by the properties of its emulsion, and by the development which it receives. The latter is dictated by the requirements of the picture. Redevelopment of the sound-track silver after bleaching is a process which goes rapidly to completion, and so is not suitable for regulating gamma. The characteristic curve of the film as a whole is the sum of the curves of the individual

layers. Varying the relative exposures of these layers, by changing the color quality of the printing light, causes a change in the composite curve. Maximum gradient is obtained when the light produces an image, the dye component of which is neutral, because then each of the individual layers contributes density throughout the range of total density. As it turns out, this condition yields the best sound prints, both variable-width and variable-density.

Because the sensitivities of the individual layers vary considerably among themselves, it is necessary to filter the printing light in order to obtain a neutral print from a black-and-white negative. A pack composed of several filters will be required. The combination of a photometric filter with color-compensating filters is recommended because it requires the least number of elements. This is important because it minimizes surface losses. Experimentally, it was found that the available exposure was doubled in changing from a 6-element to a 3-element filter pack. In printing sound, it is not necessary to include in the filter pack an ultraviolet-absorbing filter such as that used in printing the picture.

To make neutral prints of proper density on a Bell & Howell Printer, Model D, operated at 90 ft/min, it has been found necessary to use a high-intensity light system, utilizing a concave mirror and a 300-w tungsten lamp.

In selecting filters to produce a neutral image, it is helpful to employ sensitometric methods. One manner in which this can be done is as follows: First, by use of a IIb sensitometer a step tablet is made on a motion picture film, preferably on the type to be used for the sound negative. This is printed onto Type 5381 in the sound printer, using a combination of filters which is known to produce an approximately neutral image, for example, a Kodak Wratten No. 86 Filter plus Kodak Color Compensating Filters, CC-20Y and CC-10M. The print is processed *without* redeveloping silver in the sound track. Then, by trial and error, any necessary changes are made in the filter pack until a visually neutral print is obtained. Next, the blue, green and red densities of the steps of this print are determined on a suitable densitometer, and are plotted in the form of H&D ($D - \log E$) curves. This set of curves then serves as a standard with which other sets can be compared. Deviations from the standard will indicate quantitatively any changes in filters which may be required. To maintain maximum available exposure, a minimum of filters should be used. In changing a filter pack to obtain a neutral image, one should always be alert to the possibility of accomplishing this end by removing a filter rather than by adding one, for example, by removing magenta rather than by adding green.

A typical set of standard curves obtained by use of a Western Electric RA-1100-B Densitometer is shown in the right-hand panel of Fig. 1. Integral blue, green and red densities of a neutral strip were determined by employing, respectively, the "blue-printing" filter supplied with the densitometer, a Kodak Wratten No. 58 Filter, and a Kodak Wratten No. 25 Filter. As a matter of general interest, a set of equivalent neutral density curves, determined from the same neutral strip, is shown in the left-hand panel of the figure.

In densitometry of the composite silver and dye image, the visual method leaves something to be desired. The dyes absorb visible light and, therefore, contribute strongly to visual density, but they are quite transparent to infrared radiation. Since conventional sound reproducers utilize infrared-sensitive phototubes, the signal generated in such a reproducer by the sound track on Type 5381 is attributable almost solely to the silver component of the image. Visual densitometry can, therefore, be quite misleading. For example, an effective density of 1.6 in a variable-width print will have a visual diffuse density of approxi-

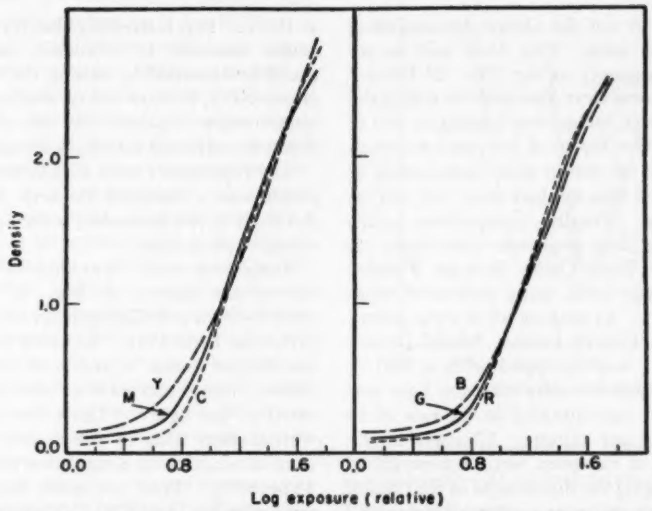


Fig. 1. Density versus log exposure for a neutral print (dye only) on Type 5381. Left: Equivalent neutral densities, magenta, M; cyan, C; and yellow, Y. Right: Integral densities, green, G; red, R; and blue, B.

mately 2.6. Consequently, it is recommended that a physical densitometer be used for reading sound-track densities. It should be equipped with a phototube of the infrared-sensitive type used in reproducers. No filter should be used in the optical system.

All sound-track densities referred to in the remainder of this paper were read on a Western Electric RA-1100-B Densitometer in which the usual blue-sensitive Type 929 phototube had been replaced by a Type 925 phototube. The heat-absorbing glass which is normally present in the optical system was removed. It has been found that densities of neutral sound track on Type 5381 read on this modified densitometer are in good agreement with the actual densities effective in a sound reproducer.

Sound Tests

Distortion, frequency-response, volume-level and signal-to-noise ratio tests have been made on Eastman Color Print Film. In variable-density prints, distortion was determined by the intermodulation method,[1] using 60 cps (cycles per second) and 1000 cps, while in variable-width prints it was determined by the cross-modulation method,[2] using a 9500-cps carrier frequency, amplitude-modulated at 400 cps. All of the negatives used were sensitometrically equivalent to the normal negatives employed in black-and-white release printing, or else they covered a sensitometric range including the normal. Variable-density negatives were exposed on Eastman Fine Grain Sound Recording Film, Type 5373, while the variable-width negatives were exposed on Type 5372.

Neutral prints were made from each negative. Prints exposed with unfiltered tungsten light were made from several of the negatives, and in some cases prints were made using tungsten light filtered by a Kodak Wratten No. 2B Filter, which absorbs ultraviolet. It will be convenient at times to refer to either of the latter two types of print as a "white-light print." The context will make it clear

whether or not the ultraviolet-absorbing filter was used. This filter will be referred to simply as the "No. 2B Filter." Experiments were also made in which the sound-track image was limited to two of the sensitive layers of the print material, but since the results were unfavorable to the use of this method they will not be presented. Finally, comparison prints from the same negatives were made on Eastman Fine Grain Release Positive Film, Type 5302, using unfiltered tungsten light. In making all of these prints, a Bell & Howell Printer, Model D, was used. It was equipped with a Bell & Howell high-intensity tungsten light system, and was operated at the rate of 90 ft of film per minute. Changes in the amount of exposure were accomplished by changing the diaphragm in the optical system, so the color quality of the exposing light remained constant. The voltage supplied to the printer lamp was held at 105 v. It is interesting that no appreciable increase in available exposure could be obtained by raising the voltage above 105 v, because the increasing color temperature required the use of more filters to maintain a neutral image.

The reproducer used in analyzing the prints was a standard Western Electric RA-1251-B Re-Recorder, with infrared-sensitive phototube.

Variable-density intermodulation curves are shown in Fig. 2. Those drawn with a solid line pertain to neutral prints on Type 5381. In order to cover the desired range of sensitometric conditions, nine negatives were used, as indicated in the figure. The curves drawn with dashed lines in the central panel were obtained from comparison prints on Type 5302. They are quite similar to the curves for Type 5381. Volume levels were also measured on the prints of Fig. 2. The prints on Type 5381 were found to

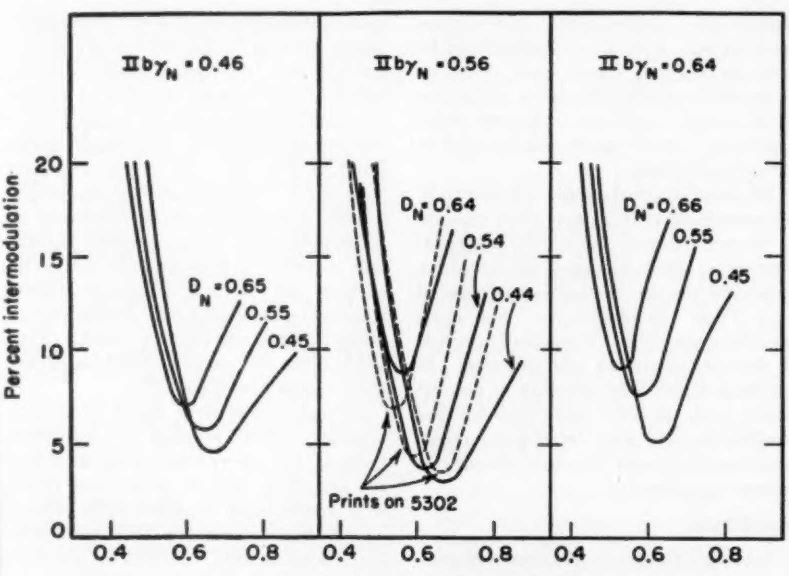


Fig. 2. Intermodulation. Neutral prints on Type 5381 from negatives on Type 5373, reference prints on Type 5302.

run from 3 to 4 db higher in volume than corresponding prints on Type 5302.

In Fig. 3 are shown additional intermodulation curves. These compare a neutral print with two other prints, one exposed with unfiltered tungsten light, and the other exposed with tungsten light from which the ultraviolet was removed. A single negative, of normal density and gamma, was used. It will be noted that the optimum print density for the white-light prints is considerably higher than that of a neutral print. At the points of minimum intermodulation, the volume level of the neutral print is 7 db above that of either white-light print. A portion of this difference is attributable to the lower optimum print density of the neutral print, the remainder to its higher gradient.

Variable-density frequency-response curves are shown in Fig. 4. These have been corrected to show film losses only; scanning-slit losses are not included.

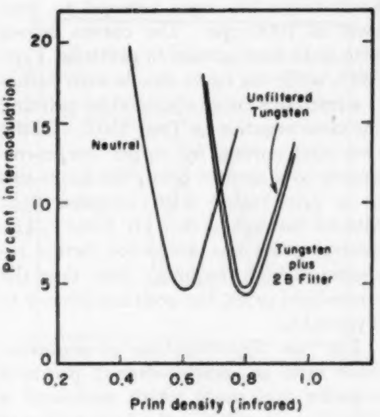


Fig. 3. Intermodulation. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5373.

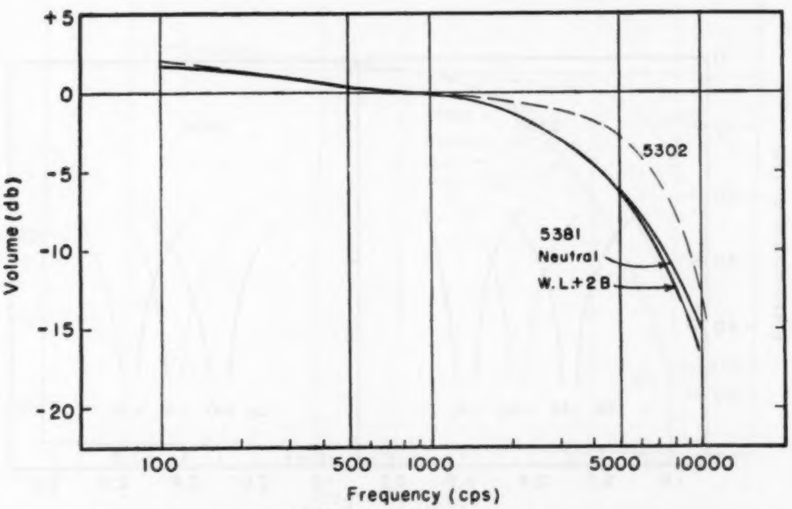


Fig. 4. Variable-density frequency response, referred to zero level at 1000 cps. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5373, reference print on Type 5302.

Each curve has been referred to zero level at 1000 cps. The curves drawn with solid lines pertain to prints on Type 5381, while the curve drawn with dashes is a reference curve obtained by printing the same negative on Type 5302. Of the two solid curves, the upper one corresponds to a neutral print, the lower one to a print made with tungsten light filtered through a No. 2B Filter. The neutral print has somewhat better response at high frequency than does the white-light print, but both are inferior to Type 5302.

For the determination of signal-to-noise ratio in variable-density prints, a negative was made which contained a 1000-cps recording, and a long section of unbiased, unmodulated track at the same density. Prints made from this negative were run on the re-recorder, and the relative outputs of the two sections were found. An 8000-cps low-pass filter was used to eliminate high-frequency noise. The signal-to-noise ratio of a neutral print on Type 5381 was found to equal that of a print on Type 5302, but that of a white-light print was 5 db lower.

To turn now to variable-width prints, cross-modulation curves obtained by using a negative recorded at several different densities are shown in Fig. 5. The family of curves at the left refers to neutral prints on Type 5381, while that at the right refers to prints on Type 5302. In each case, curves are shown for three different print densities. Negative-density latitude does not vary greatly with print density and, at a cross-modulation product of −32.5 db, it averages 0.26 for prints on Type 5381, and 0.30 for prints on Type 5302. The optimal negative densities for the prints on Type 5381 are about the same as those for the prints on Type 5302. It is to be noted that the corresponding print densities are about 0.3 higher on Type 5381 than on Type 5302.

Another set of cross-modulation curves is shown in Fig. 6. In this case, the negative was exposed at a single density. Each print made from this negative was exposed to a series of print densities. At

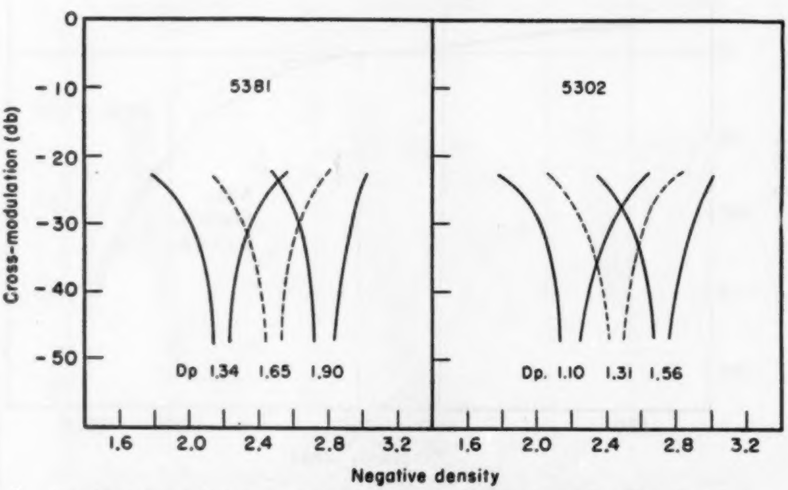


Fig. 5. Cross modulation, three different print densities, negative density variable. Neutral prints on Type 5381 from negatives on Type 5372, reference prints on Type 5302.

the left is shown a pair of curves for white-light prints. The left-hand curve of this pair, drawn with dashes, corresponds to a print made with no filter, while the other curve refers to a print made with an ultraviolet-absorbing filter in the light beam. A reference curve, from Type 5302, lies near the center of the figure. The curve at the extreme right is for a neutral print on Type 5381. All four prints have a print-density latitude of approximately 0.23 at a cross-modulation product of −32.5 db. The optimal print density of the neutral print is considerably higher than that of a print on Type 5302. White-light prints, however, have optimum print densities which are too low for good wearing quality.

Figure 7 presents frequency-response curves measured on variable-width prints. The individual curves have been referred to zero level at 1000 cps. Three prints on Type 5381 are represented by

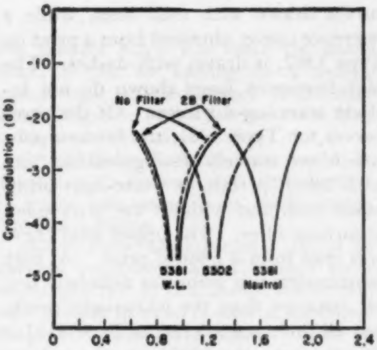


Fig. 6. Cross modulation, single negative density, print density variable. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5372, reference print on Type 5302.

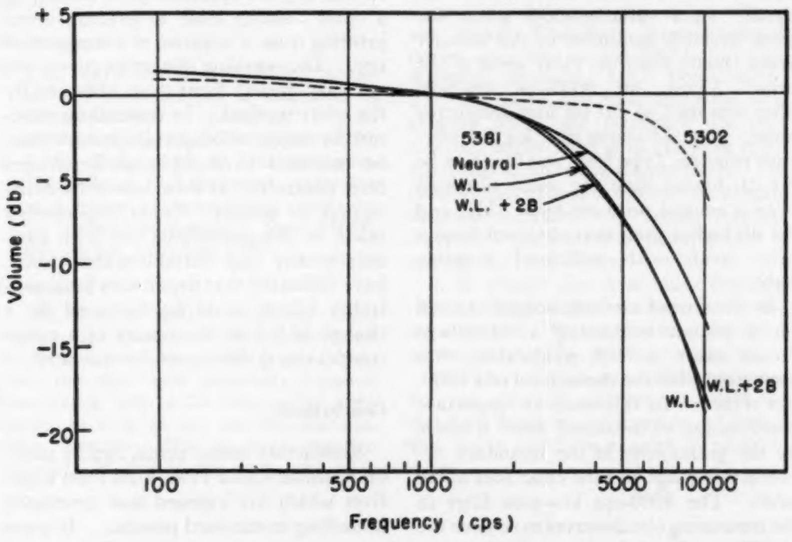


Fig. 7. Variable-width frequency response, referred to zero level at 1000 cps. Comparison of white-light and neutral prints on Type 5381, from normal negative on Type 5372, reference print on Type 5302.

curves drawn with solid lines, while a reference curve, obtained from a print on Type 5302, is drawn with dashes. The high-frequency losses shown do not include scanning-slit losses. Of the three curves for Type 5381, the bottom pair, which are scarcely distinguishable from each other, pertain to white-light prints made with and without the ultraviolet-absorbing filter. The upper solid curve was read from a neutral print. At high frequencies, this print has definitely better response than the white-light prints, but all three are inferior to Type 5302 in this respect. At 1000 cps, the volume level of the neutral print was 0.9 db lower, and that of each white-light print was 1.5 db lower, than that of the print on Type 5302.

Signal-to-noise ratio in variable-width prints was determined by two different methods. The first method is similar to that used for variable density, the level of unmodulated, unbiased track being compared with that of a recorded 1000-cps signal. In a variable-width print, the noise which is measured in this manner arises chiefly from the clear areas of the print. Again, an 8000-cps low-pass filter was used to cut off high-frequency noise. Signal-to-noise ratio for the reference print on Type 5302 was found to be 3.1 db higher than the value obtained from a neutral print on Type 5381, and 2.4 db higher than that obtained from a print made with unfiltered tungsten light.

By the second method, noise measured on a section containing a 10,000-cps record made at 80% modulation, was compared with the signal level of a 1000-cps record. In this case, an important contribution to measured noise is made by the granularity of the boundary between the image and the clear area of the print. The 8000-cps low-pass filter in the measuring circuit serves to remove the 10,000-cps signal, leaving only the components of noise with frequencies below 8000 cps. Signal-to-noise ratio for the reference print on Type 5302 turned out to be 1.5 db higher than the value for a neutral print, and 1.1 db higher than the value for a print made on Type 5381 with unfiltered tungsten light.

It will be noted that both types of variable-width noise measurement indicate a slight superiority of the white-light over the neutral print. The low print density of the white-light print, however, would probably lead to a reversal in this relationship after repeated projection.

As indicated previously, the entire series of tests just outlined was printed without varying the lamp voltage. The color quality of the exposing radiation was thus held constant throughout a given print. Limited variable-density intermodulation tests were made in which the exposure of "neutral" prints was varied by changing the lamp voltage. No change was made in the filter pack; therefore, the color balance of the image changed with density level. The diaphragm opening, however, was carefully chosen to yield optimum print density at a color balance close to neutral, when printing from a negative of average density. The resulting distortion curves did not vary greatly from those obtained by the other method. In controlling exposure by means of lamp voltage, care must be exercised to avoid large departures from neutrality, as these would be detrimental to quality. Other experiments made in this connection, on both variable-density and variable-width prints, have indicated that departures from neutrality which could be corrected by a change of 0.1 in the density of a color-compensating filter, can be tolerated.

Conclusions

Satisfactory sound prints can be made on Eastman Color Print Film from negatives which are exposed and developed according to standard practice. It is not necessary to use negatives of abnormal density or contrast. The dye-plus-silver sound track which is obtained is well suited to existing reproducers.

Prints should be exposed with radiation of a quality which will produce an approximately neutral image in the sound track. Printing with unfiltered tungsten light is not recommended for either variable-density or variable-width sound tracks, because in each case the resulting prints are inferior to neutral prints in some respects. Although an ultraviolet-absorbing filter is necessary to preserve correct color balance in making prints from color-picture negatives, it has no appreciable effect on the balance to tungsten light when printing from black-and-white sound negatives.

Acknowledgment

We are pleased to acknowledge the assistance given by several members of the Color Process Development Department, Kodak Research Laboratories, with whom we have conferred on problems relating to exposure and development.

References

1. J. G. Frayne and R. R. Scoville, "Analysis and measurement of distortion in variable-density recording," *Jour. SMPE*, vol. 32, pp. 648–673, June 1939.
2. J. O. Baker and D. H. Robinson, "Modulated high-frequency recording as a means of determining conditions for optimal processing," *Jour. SMPE*, vol. 30, pp. 3–17, Jan. 1938.

Discussion

John Stott: I believe Eastman Color Positive Film has speed relationships within the three layers which make it possible to print this film with essentially tungsten illumination with a 2B filter in the light source, so long as you use the Eastman Color Negative Film as your negative material. If that is the case, why is it not possible when you make the sound track, if you are looking for a neutral sound track, to use a piece of Eastman Color Negative Film that has been fixed out and use that as your filter?

C. H. Evans: I think that would be possible. We haven't used that method. It might take some color compensating filters in addition.

John P. Byrne: My question is one of an amateur regarding color. I don't know anything about it, practically, but we will have to think in terms of color at the Signal Corps from now on, I believe. How do you get your three separate curves, each one from a single emulsion layer? Are they exposed in a sensitometer to three different filters to get the cyan, magenta and yellow values? If this is the case, how do you superimpose those three to get your density equivalent?

Mr. Evans: Do you refer to those curves which we showed in Figure 1?

Mr. Byrne: Yes.

Mr. Evans: Those were read on the entire film. That is, we had a single neutral densitometric dye strip, without any silver. The three integral density curves were read on the ERPI (Electrical Research Products, Inc.) Densitometer. The first curve was read using the blue printing filter; the procedure was then repeated on the same strip using the green filter, and again, using the red filter. The densities determined in this way are integral densities and they don't really separate completely the individual contributions of each of the three layers.

J. G. Frayne: Are these losses that you report at high frequencies inherent in the dye structure? Or are they brought about by the silver sulfide in your process?

Mr. Evans: This is not a sulfiding process. You just get silver and dye. I would say that such losses are inherent in a tri-pack film, where you have to print in all three layers.

Simultaneous High-Speed Arc Photography and Data Recording With a 16-Mm Fastax Camera

By EUGENE L. PERRINE and NELSON W. RODELIUS

In order to correlate photographs with other recorded data, the optical system of a galvanometer oscillograph was modified so that it could record on the film in the exposure aperture of a 16-mm Fastax camera. The addition of the galvanometer system required no permanent alterations of the Fastax camera and provided a record in the form of a spot which moved horizontally in the field of view when the film was projected.

As HAS BEEN the case in most other high-speed motion pictures of welding arcs, the photographs made by us were only one phase of a study of the arcs. Other information was recorded simultaneously by pen recorders and a six-channel galvanometer oscillograph. After the experiments were partially completed it was found impossible to correlate the action in the motion pictures with the other recorded information. To overcome this difficulty, a galvanometer was added to the Fastax so that the same signal that was recorded on one channel of the oscillograph could also be recorded on the Fastax film. With this arrangement, it was possible to relate any action seen in the picture to variations in the recorded data.

The photographs required for welding arc studies are close-ups. Usually only the tip of the electrode, the arc, and a small area of the piece being welded are included in the field covered. In most cases a field one-half inch high was adequate. To cover this area without placing the lens too close to the arc, a 113-mm focal length, $f/4.5$ Bausch & Lomb Tessar was used. The mounts for this and similar lenses used in our laboratories were made in our own shop. They consist of a brass tube with adapters to fit the different lenses and a series of interchangeable tubes of various lengths which telescope with the lens tube and are fitted to the lens mount of the camera (Fig. 1). With these tubes and a series of lenses ranging in focal length from 17 mm to 6 in., we are able to focus at any distance from infinity to less than one inch. They make possible any desired image size on the film up to a magnification of ten times.

The brightness of various welding arcs differs over a range of more than one hundred to one, but in all cases it is very high. In addition to the use of small apertures, it was necessary to use filters

Presented on May 2, 1951, at the Society's Convention at New York, by Eugene L. Perrine and Nelson W. Rodelius, Armour Research Foundation of Illinois Institute of Technology, 35 West 33 Street, Chicago 16, Ill.

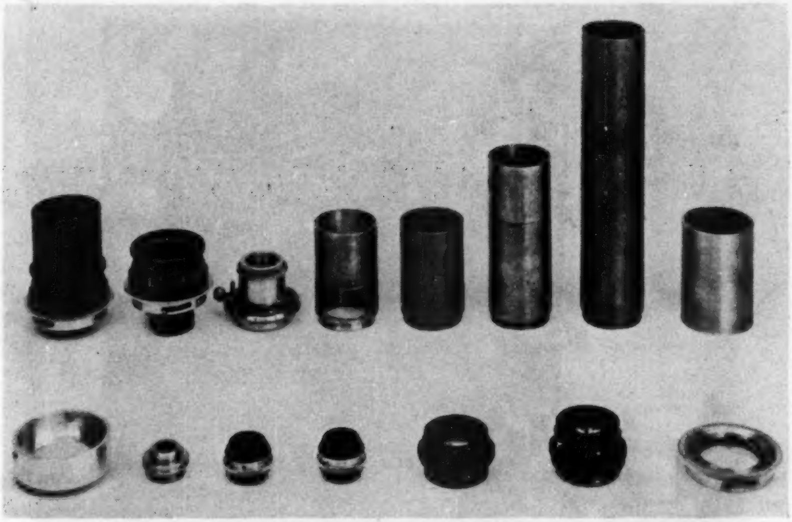


Fig. 1. Lenses, adapters, and extension tubes used with the Fastax camera.

to reduce the light reaching the film. Filter combinations having factors of about fifteen were used with Eastman Super X film, at 5000 frames/sec, and apertures of from $f/16$ to $f/64$. These filter combinations were also used to select various portions of the spectrum when it was desirable to accentuate certain parts of the arc. Pictures made with Kodachrome film and neutral-density filters were found less satisfactory than those made on black-and-white film, because of the shorter scale of the Kodachrome. A special holder was constructed for the filters (Fig. 2). This holder also held a cover glass which protected the filters from splattering metal.

A carriage mounted on a track carried the welding electrode. A camera support was constructed and attached to the carriage so that the camera always followed the arc during the operation. A microswitch mounted on the track was operated by the carriage to start the camera. Manual operation of the camera was sometimes more desirable in

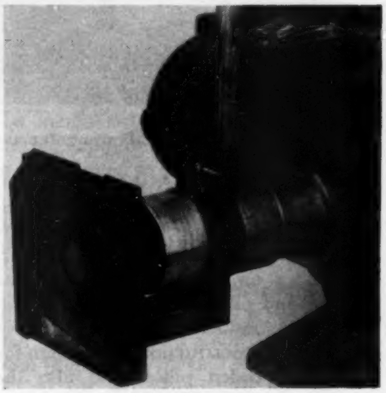


Fig. 2. Filter holder.

order to make possible the photographing of the arc at the most advantageous moment, e.g., when the arc was least obscured by smoke.

The timing-light in the Fastax was used to provide a record of camera speed, but after a few films had been viewed and the data recorded by the

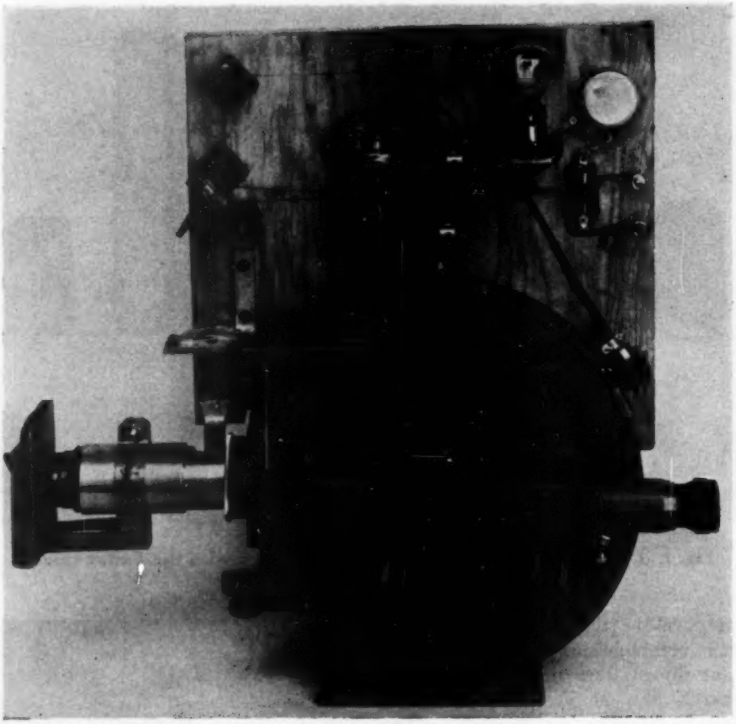


Fig. 3. Galvanometer assembly on the Fastax camera.

oscillograph examined, it was apparent that more than a record of camera speed was needed to relate the action to the recorded data. The use of synchronizing pulses on the timing-light of the camera and one channel of the oscillograph was considered. This would have required the construction of a system for generating coded pulses and also the additional work of a frame-by-frame examination of the film to associate the marks on the edge of the film to the related frame. Instead of using the synchronizing pulses, a way was devised for mounting one of the galvanometers from the oscillograph on the Fastax camera.

In making this addition to the camera, two major problems had to be solved. First, the galvanometer system had to be attached to the camera in such a way that the future operation of the camera was unimpaired. It was desirable, although not mandatory, to make the additions in a fashion which would leave the camera available for other work during any break in the arc study. Second, the light from the galvanometer optics had to be improved to provide adequate exposure on the faster-moving film of the camera.

The first of these problems was solved by folding the optical path of the galvanometer system and bringing the light beam into the camera through a hole cut in the top of the lens extension tube. Figure 3 shows the entire assembly, including galvanometer, light source, mir-

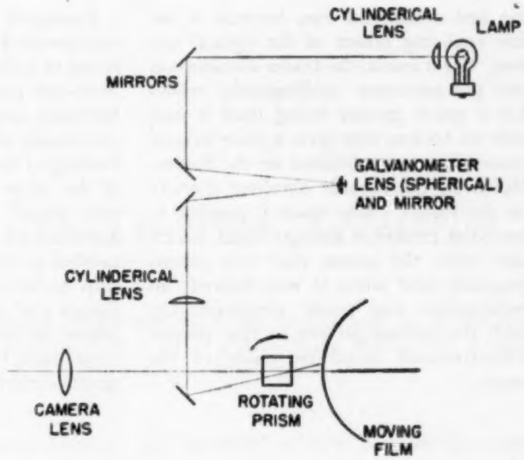


Fig. 4. Optical system of galvanometer mounted on Fastax camera.

rors and lenses. This assembly was mounted on a piece of $\frac{3}{4}$-in. plywood which provided a rigid support; it was easily held on the side of the camera with two clamps, and could be temporarily removed from the camera without loss of adjustments. First-surface mirrors were used throughout. The mirror mounted inside the extension tube was placed sufficiently below the optical axis of the camera so that none of the light passing from the camera lens to the film was intercepted. This was to avoid any change in the exposure of the picture. Because the apertures used were small, this was easily accomplished. Interference would probably be inevitable with high relative apertures. Focus of the light spot and amplitude of the galvanometer were set with the lens removed from the camera so that the spot could be observed directly in the exposure aperture. The view-finder could not be used because the light entered the aperture from below the axis and was imaged at the top of the aperture. Rays following this path never enter the relay lens in the view-finder.

When operated at 5000 frames/sec, the film in the 16-mm Fastax camera moves about five times the paper speed used in the oscillograph from which the galvanometer record was obtained. The paper has a sensitivity nearly as great as Eastman Super XX film, so that no exposure increase is obtained with the recording material. The light source was a 6–8 v, 50-cp auto headlight bulb which was turned so that the optical system imaged the edge of the filament. To increase the brightness of the spot during exposure, the voltage on the bulb was advanced to just below the burn-out value. Also, two cylindrical lenses were added to the system. One placed near the lamp imaged it on the moving mirror of the galvanometer. A second cylinder, just above the lens extension tube, shortened the line image resulting from the first cylinder to a slightly elongated spot (Fig. 4). This spot was of adequate brightness to compensate for the increased writing speed in the camera.

The galvanometer record appeared as a spot which moved horizontally in the bottom of the frame of the projected motion pictures. The spot size was slightly larger than the thickness of the coiled filament in the lamp used. Only slight improvement could have been obtained by using a slit over the lamp or

the first cylindrical lens, because of the low resolving power of the optical system. As a result, the traces obtained on the galvanometer oscillograph, which has a much greater swing than is possible on 16-mm film, gave a more precise record than was obtained on the Fastax. However, the records obtained directly on the Fastax frame made it possible to see what electrical changes were associated with the action that was photographed, and when it was desired, an oscillogram was made simultaneously with the motion picture so that precise measurements could be made of the trace.

Examples of other uses for the galvanometer–Fastax system are: (1) the firing of a flash bulb where the filament burn-out time is to be related to the burning; and (2) the operation of an electrically driven impact tool where the loading of the motor at different portions of the cycle is being studied. The system would be useful in many other applications where additional data are needed to determine the exact relationship between controlling or controlled signals and the action photographed, or where several slightly different operations must be associated with their respective electrical counterparts.

Forum on Motion Picture Theater Acoustics

THIS FORUM was sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, and was held on June 7, 1949, at New York, William H. Rivers presiding, and Professor Leo L. Beranek acting as Moderator.

Chairman William H. Rivers: This is rather an unusual type of meeting for us to have, but it seems highly worth while. The main gain from this meeting is the technical discussion and the conclusions that may be taken away with us. [After announcements, Mr. Rivers turned the meeting over to the moderator.]

Moderator Leo L. Beranek: I think we will do best today if we treat this meeting as an informal one, and lay ourselves open to asking and answering questions, without worrying about whether this is going on the record or not.

This Forum came to be organized as the result of a letter received a scant month past, and addressed to the SMPE Secretary, from Mr. Lucas, of the British Thomson-Houston Company, Ltd., saying that James Moir was going to be in New York about this date. We thought it would be helpful, knowing the papers that he has published in this field, to learn his thoughts on motion picture theater design, so we cabled him and he consented to be with us today.

We thought it might also be interesting to learn about motion picture theater design in the Scandinavian countries. Uno Ingard, of Chalmers University, Gothenburg, Sweden, studying at MIT in the Acoustics Laboratory, was asked if he would speak on the state of Scandinavian motion picture theater design. He hesitated at first because, he said, there are other people who are experts in this field, and he didn't want to speak as one of the experts. But he did consent to tell us the state of the art as he knows it.

We felt that the important objectives of this meeting should be: (a) to exchange information on an informal basis; (b) to establish what, if any, are the essential differences between practices in Europe and practices in the United States; and (c) to gain ideas on how to better the practices of our own countries.

Having obtained the interest of our Forum visitors, we proceeded to assemble a panel of local experts, who will lead the discussion and answer questions from the audience. These men reserve the right to change their minds if they think better of their answers at some later date. [The panel personnel are listed on p. 159 of this *Journal*.]

I do not wish to give a speech, but I would like to give the general basis of the subject of our discussion.

When sound pictures were first being tried out around the country, they were shown in auditoriums, with rather bad acoustics, that is, the reverberation times were high. It soon became obvious that something would have to be done to the halls if sound motion pictures were to be acceptable. So, a trend developed in the

direction of placing a lot of absorbing material in the rooms, with the result that most theaters became very "boomy." This happened because the absorbing materials selected were efficient only at the higher frequencies. Then, studies were made in the laboratories of some of our larger manufacturers of sound systems. These studies led to the establishment of criteria for motion picture design.

One particular set of studies led to the issuing of a bulletin by the Research Council of the Academy of Motion Picture Arts and Sciences on May 30, 1932, on "Theatre Acoustic Recommendations." In it is a graph of optimum reverberation times versus room volume. Also, Potwin and Maxfield published a paper in which they set forth another curve of optimum reverberation times, much the same as the SMPE curve for small rooms, but indicating somewhat higher reverberation times for large rooms.

It has been my general observation that the recommendations set forth by the Academy of Motion Picture Arts and Sciences and by Potwin and Maxfield have not been adhered to in actual theater design in this country. I believe that most movie theaters are much deader than the optimum reverberation characteristics shown in these booklets would indicate.

I sincerely hope that we shall discuss the trends in the design of motion picture theaters, both with regard to reverberation time and room shaping. I would not be surprised if we should agree that the SMPE characteristics need revising. (At this point, Dr. Beranek introduced Mr. Moir who presented his paper, for which see the following pages of this *Journal;* then Mr. Ingard presented his paper which is also in this issue.)

Pulse Methods in the Acoustic Analysis of Rooms

By J. MOIR

Experience in installing large numbers of a standard sound-film equipment in theaters indicated that sound quality was not related to the overall frequency characteristic or the reverberation time. A pulse technique is described which gives a direct picture of the direct and reverberant sound at any location. The value of the reverberation-time concept as presently defined is questioned and recommendations for the optimum design of theaters are given, based on the results of pulse analysis.

There appears to be little doubt that most first-order defects in the acoustical performance of a room are removed by the application of Sabine's analysis[1] and recommendations. Experience appears to indicate, however, that the second-order defects, though still important, are not corrected by more meticulous application or by elaboration of Sabine's analysis. This is not a statement that can be shown to have precise mathematical justification, but is something that grows upon one as a result of daily contact with the problems.

In our particular case, we were engaged before World War II in installing sound-film reproducers of standard design in a large number of theaters, and we found that the results at the patron's ear varied all the way from very good to "not so good." The differences were sufficient to justify an investigation. As a first step, our Service Division was asked to provide us with a list of theaters in order of merit, all theaters listed having nominally identical equipment. When the list was studied in detail it was found that theaters listed as "above average" were all praised because of their "good intimacy," a factor which we think is termed "good presence" in the United States. The importance of this factor has been further confirmed during additional postwar investigations into the public preference in sound quality. In two areas checked, theaters having equipment of 1930–1932 design were preferred, though postwar equipment made by all the leading firms was available in the area. The result is surprising because the frequency response was very poor and wow and flutter were high, by current standards. In both

Presented on June 7, 1949, as part of the Forum on Motion Picture Theater Acoustics, sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, held at New York, by James Moir, British Thomson-Houston Co., Ltd., Rugby, Warwickshire, England.

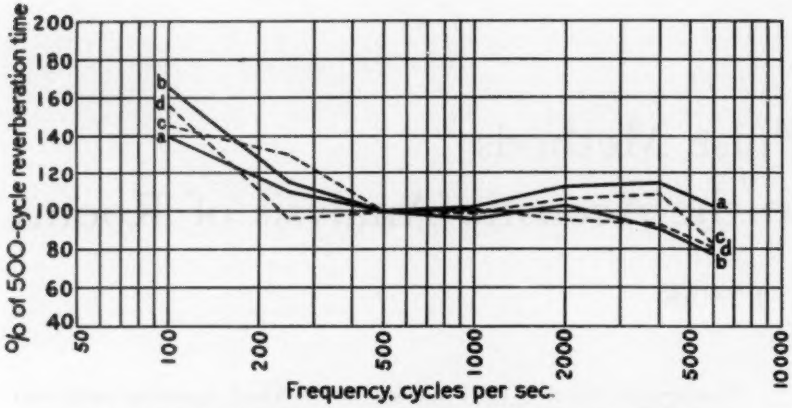


Fig. 1. Reverberation time in different positions in auditorium. a and b: sound quality good; c and d: sound quality bad.

theaters, the "intimacy" was particularly good.

Reverting to the prewar investigation, after a preliminary check to make certain that no normal defects existed, we began to make a more extensive survey of those factors such as acoustic frequency response, reverberation time, etc., factors which are known to be of importance though they are not normally checked in detail on every installation.

Frequency response was not found to present any consistent explanation of the variation in results and this point will not be further discussed.

For various reasons, the differences were considered to be acoustical and we therefore made a more detailed survey of the reverberation time/frequency volume relation. No consistent explanation was found. The results in one particular theater, typical of many others, are indicated in Fig. 1, from which it will be seen that the differences which do occur are small and randomly distributed. The test technique was conventional, a Neuman high-speed level recorder having been used, while the depth and frequency of the modulation of the test tone could be varied over wide limits.

We did have some indication, however, that a greater proportion of the good theaters were to be found with reverberation time below, rather than above, the optimum time/volume relation. The results of twelve of the theaters in the first group tested are shown in Fig. 2. At the time, this was thought to be due to the preferred reverberation time/volume curve being nonoptimum, but we now feel that it is of more fundamental significance. This point will be discussed presently.

Experience gained during this part of the investigation confirmed that the sound-quality preference was based almost entirely upon the closeness of association of sound and picture, the quality we termed "intimacy," and we came to regard this as being connected in some way with the ratio of direct to reflected sound.

Preliminary attempts to measure this were made, but without success until we devised the pulse techniques to be described. This enabled the direct and reflected components to be separated on a time basis and is probably best understood by referring to Fig. 3, a schematic layout of the equipment used.

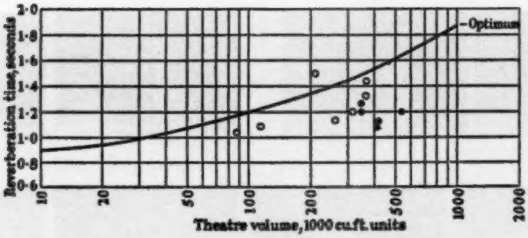


Fig. 2. Theater volume/reverberation time/sound quality results. Black circles: sound quality above average.

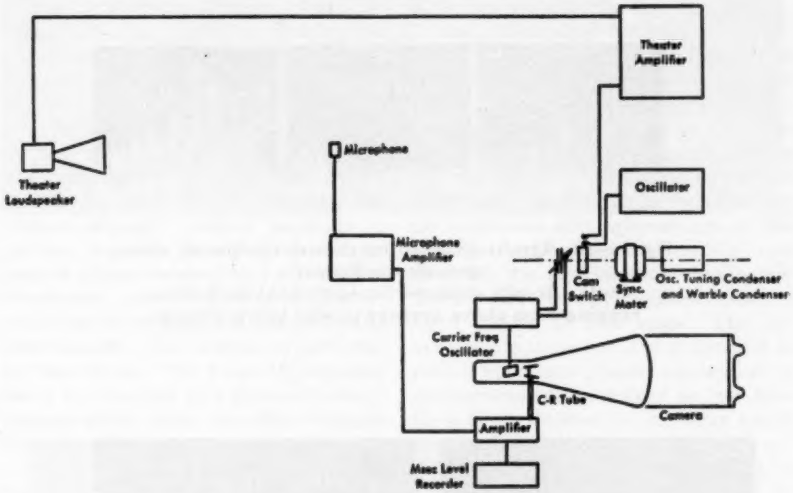


Fig. 3. Setup for acoustic survey in auditorium.

The output from a variable-frequency (audio) oscillator is applied to the input of the theater amplifier through a motor-operated cam switch, which can be set to close circuit for any period between 0 and 50 msec, repeating this at intervals of 1 sec. The frequency of the test tone is set on the oscillator dial in the normal way. This tone pulse is radiated by the theater loudspeakers and is picked up by a sound-cell type of microphone, amplified and applied to produce a vertical trace on a cathode-ray tube. Horizontal deflection of the cathode-ray-tube beam is initiated by the application of the pulse to the loudspeakers, the spot moving uniformly from left to right in about 0.5 sec. Thus, in free space, with no reflections present, the cathode-ray-tube picture consists of a vertical pulse spaced from the origin by a distance proportional to the distance between loudspeaker and microphone. With reflections present, each reflected pulse is spaced from the initial pulse by an amount directly proportional to the difference in path length between the direct and reflected components.

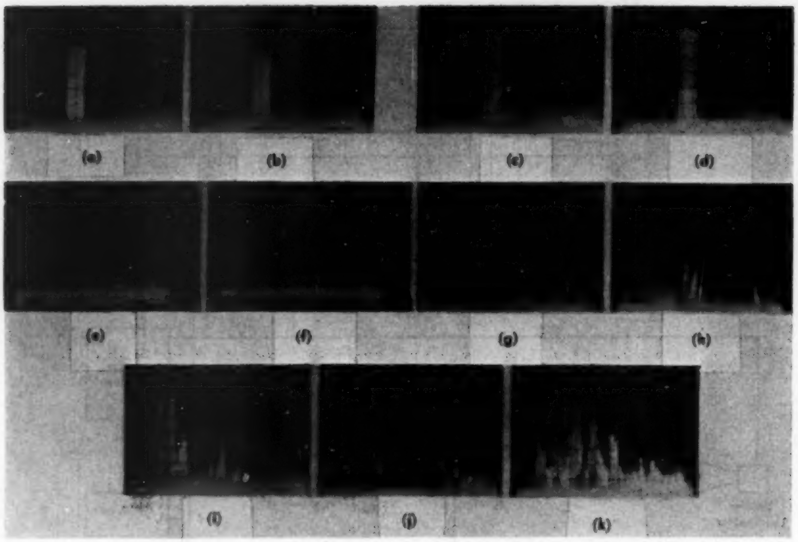


Fig. 4a–4d. Results obtained for theater equipment under open-air conditions;
4e–4k. Results obtained for equipment in theaters ranging from above average to well below average.

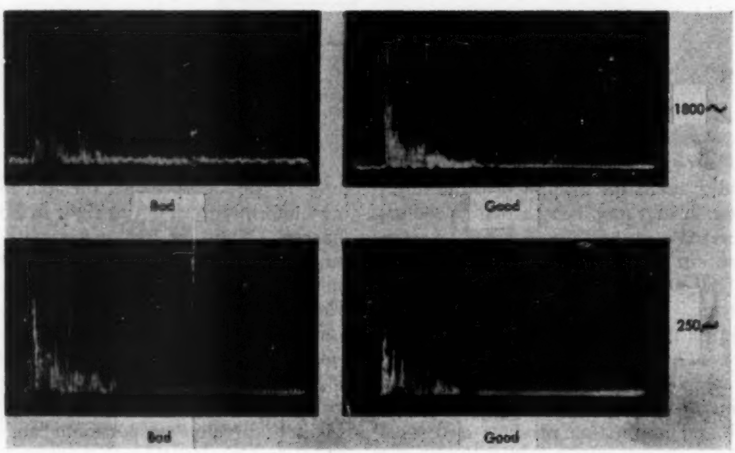


Fig. 5. Changes from bad to good sound quality.

The first four pictures of Fig. 4 illustrate the results obtained for the theater equipment under open-air conditions. The pulse at the input to the theater amplifier is shown in Fig. 4a, the resulting pulse at the amplifier output, in Fig. 4b. Speaker performance is illustrated by Figs. 4c and 4d, taken 4 ft from the high-fidelity horn on the axis, 4c and 30° off the axis, 4d. Pulse shape is seen to be substantially unaltered by the electroacoustic equipment.

The remaining pictures, Figs. 4e through 4k, are selected to show typical results in theaters ranging from above average, Fig. 4e, to well below average, Fig. 4k. In the good location, Fig. 4e, the picture is seen to consist of a well-defined direct pulse followed by a continuous structure of reflections 15 db below the direct sound, whereas the "below average" theater produces a picture, Fig. 4k, in which the direct pulse is almost obscured by a whole series of reflected pulses of greater amplitude, extending for at least 300 msec after the direct sound. It is worthy of note that in this theater, the frequency-response curve was the best of a group of twenty theaters tested about that time, whereas the sound quality was rated as the worst of the group. The reverberation time was close to, but a little above, the optimum value.

Theaters in which good and bad listening positions occurred were of particular importance in the investigation, insofar as all other factors remained constant. Figure 5 illustrates a particular example, where the Service Division was able to draw our attention to two seating positions, fairly close together, but giving widely different subjective results. Pulse pictures taken at two frequencies in both locations are shown in Fig. 5 as typical of our findings, and it will be seen that strong reflections occur in this bad location about 100 msec after the direct sound.

A large number of similar results could be quoted, but it is probably more to the point to mention that we have found no instance of a picture, similar to Fig. 4k, being obtained at a point at which the sound quality was considered to be good. This is true, irrespective of whether the reverberation time was above or below the optimum.

It should be noted particularly that the test method checks the combination of hall and loudspeaker. In a theater it is this combination that is important, for it has been possible to minimize many hall defects by appropriate horn design.

The relationship between reverberation time and the pulse picture is of interest. If a uniform rate of decay of the total sound-energy density is secured, an attenuation of 15 db in 50 msec corresponds to a reverberation time of 0.2 sec, a figure which is certainly on the short side. The figure of 50 msec can be considered only approximate at this stage in the investigation, but if it were doubled, the reverberation time would still be well below any suggested optimum for a theater of 1500 seats. The discrepancy is large and one is tempted to reflect upon our present conception of reverberation time, defined as "the time for a 60-db decrease in the mean sound energy density." It would appear unnecessary to consider the contribution of reflected components attenuated by more than 20 to 30 db. If the sound-energy decay in an enclosure were, in fact, a true exponential curve, neglect of the section of the decay curve below -30 db would not alter the reverberation time as now defined. However, experimental evidence supported by theoretical conclusions suggests that a true exponential decay is the exception rather than the rule. A typical decay curve, taken with a frequency-modulated tone is indicated in Fig. 6, where at least four different rates of decay might be deduced. If a modulated test tone were not used, the departure from a smooth exponential curve would be still greater, and we are inclined to believe that a test technique tends to be judged by its efficiency in

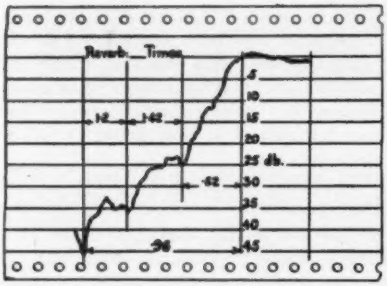


Fig. 6. Multiple decay rates.

turning a nonuniform decay into a smooth exponential decay. In doing this, we rather suspect that much that is of importance is obscured.

We would suggest that a listening point is poor if there is discrete mid-frequency reflection delayed by more than 50 to 100 msec and attenuated by less than 20 db. If this is correct, we should not be worrying about decay periods of 60 db or time intervals in seconds, but should direct our attention to the details of the decay during the first 20 db (or perhaps 100 msec), as we believe that the acoustical character of a room is almost completely determined during this initial time interval. There appears to be strong evidence to support a review of our reverberation–time definition, to place more weight on the initial 20 db of decay.

Earlier in the paper it was noted that preferred theaters appear to fall below, rather than above, the current optimum curve. On the basis of the results reported, it is suggested that this is probably not due directly to the fact that the best reverberation time is to be found on any alternative optimum curve, but is due to the decrease in the chance of getting echoes of high amplitude and long delay as the reverberation time approaches zero. It is believed that if the delayed echo problem were separately controlled, much higher values of reverberation time would be preferred.

The last war brought the investigation to a standstill and, as the building of new theaters in England has been entirely suspended until such time as war-damaged housing is restored, we have had no opportunity of following a design from the drawing-board stage to the final pulse testing, but we have had considerable opportunity to compare pulse results with what we would predict from the plans of the theater.

Let us consider just what we have found from pulse testing and how best to use that information in new designs of theaters.

1. Good sound appears to be associated with a strong direct signal followed by a reasonable amount of low-level reflection to provide room color.

2. The permissible intensity of a discrete reflection is approximately inversely proportional to the time it is delayed behind the direct sound.

3. All discrete reflection should be reduced by at least 20 db if it occurs more than 50 msec after the direct sound.

4. The sound source and all early reflections should subtend the minimum angle at the listening position.

5. There should be no sharp changes in the acoustic impedance along the hall.

As applied to the design at the drawing-board stage, it is advisable, first of all, to apply Sabine's or Eyring's equation to correct the reverberation time in the normal way. When doubt exists, it is well to err on the side of making the reverberation time slightly lower than the present optimum. The reverberation-time frequency characteristic should be controlled, the Knudsen–McNair relation being the best we can suggest, though we suspect that the "rise" called for at the bass end is somewhat excessive.

Regarding theater-shape ratios, a width of 0.7 × length and a height of 0.35 × length appear reasonable, though we regard this sort of data as a gross oversimplification of the problem, to be used only in the very first stages of design.

Though the prewar British standard of

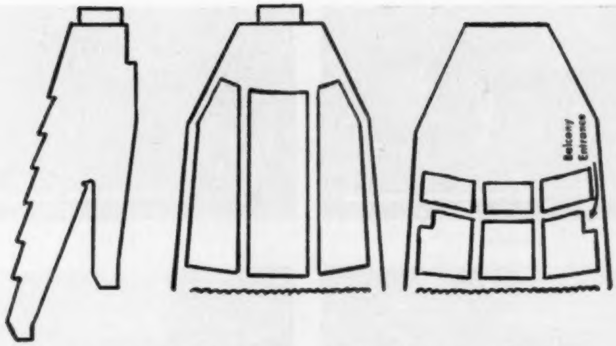


Fig. 7. General indication of preferred shape of theater.

furnishing approximately 140 to 150 cu ft per seat has given satisfactory results, good results have been secured between 120 and 180 cu ft per seat.

When absorbent material has to be added to correct the reverberation time, we regard the ceiling as the least desirable location. Energy flow between floor and ceiling is heavily attenuated by concentration of absorption on the floor, so that it appears desirable to confine any additional treatment to attenuating energy flow in the other modes.

To secure good intimacy, we would suggest the following:

1. Concave surfaces should be avoided, particularly where they face the sound source. A concave back wall is particularly harmful.

2. Large flat surfaces should not be placed where high-intensity direct sound can fall upon them. Diffusion is generally better than absorption, but regular patterns of simple diffusing surfaces should be avoided. Excess diffusion produces a characterless performance. The wall shapes should be such as to avoid echoes having a delay of more than 60 msec occurring at any point within the seating area.

3. A proscenium arch should be avoided and the cross section of the hall should change uniformly.

4. Gangways and entrances should be placed against the sidewalk and not in the center of the theater, a position generally containing some of the best listening areas. (Figure 7 is a general indication of the preferred shape.)

It is appreciated that these suggestions may conflict with building, fire, or site restrictions, but they have been idealized as requirements to be approached as closely as circumstances permit.

When considering cathode-ray tube methods of presenting acoustic data, it is dangerously easy to produce pictures containing so much information that they cannot be readily related to the results of subjective listening tests. The ear is almost insensitive to phase differences which produce large changes in a cathode-ray-tube picture. Because of this, and also because we are at the "crawling" stage in pulse analysis, it is necessary to present the simplest picture. This is met by radiating a pulse with the simplest possible frequency spectrum, a pulse of audio tone several cycles long. The frequency spectrum of a pulse of fixed length increases in complexity as the number of cycles in the pulse is reduced, and there is, therefore, some point in using a pulse consisting of a fixed number of cycles. We have found, however, that this is not justified in view of the decreasing importance of the lower

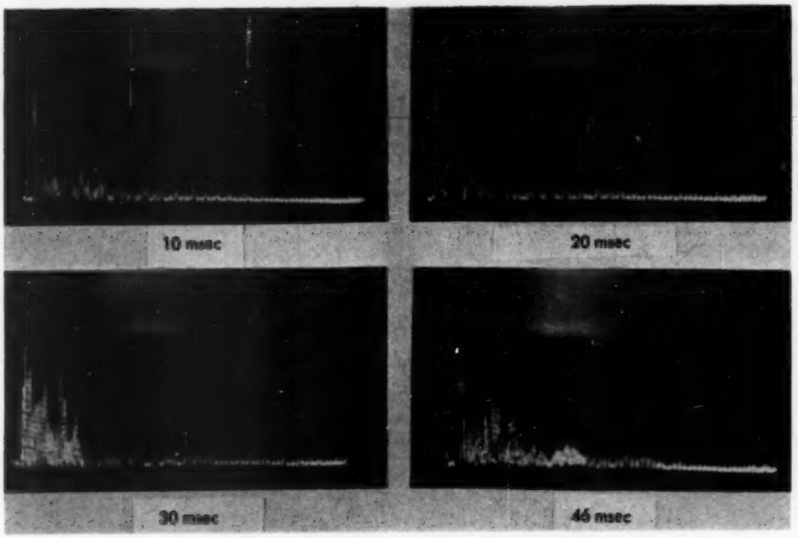


Fig. 8. Changes that occur as the pulse length is increased from 10 to 46 msec.

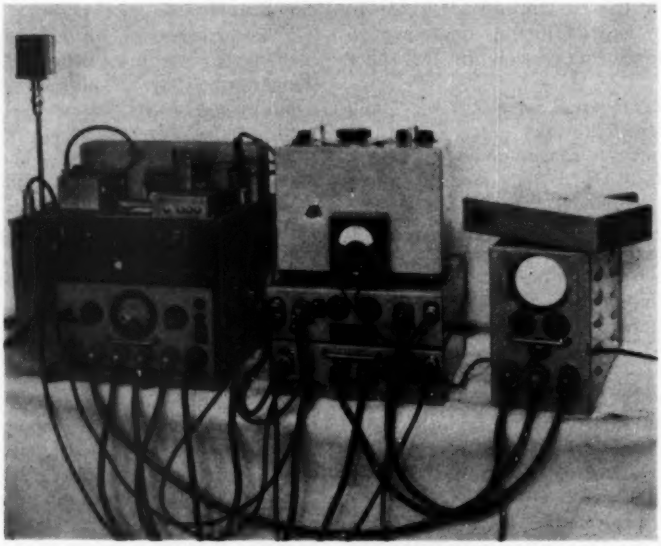


Fig. 9. Test equipment by Messrs. Owen and Webb.

frequencies in controlling intimacy. This has led to our standardizing a pulse length of 10 to 20 msec.

Other investigators have chosen to use short pulses generally produced by a spark discharge, but in our experience this presents so much information covering such a wide frequency band that it defies analysis.

As the pulse length is increased above 20 msec, the pulse pictures tend to lose their simple character due to interference between pulse components that arrive at the microphone position by paths of differing length. Figure 8 is an example of the changes that occur as the pulse length is increased from 10 to 46 msec.

Experience tends to indicate that our subjective assessment of sound quality is in good agreement with the results using a 10- to 20-msec pulse.

While we are certain that pulse methods are a powerful new weapon in exploring an auditorium, we feel that there is still much to be done. At present there is insufficient mathematical background and while we know that strong reflections have deleterious effects upon sound quality, we also know that a complete absence of reflection can lead to unsatisfactory results. The basic question "How much reflection do we want?" can be answered only in broad terms.

Change in our viewpoint and requirements during the investigation led to considerable modification in the test equipment. More recently, the equipment has been carefully rebuilt by Messrs. Owen and Webb as illustrated by Fig. 9, the complete equipment packing into two cases approximately 23 × 16 × 12 in. The basic principles remain as illustrated by Fig. 3.

The pulse technique described was developed during 1937–1940 in close association with C. A. Mason and is more fully described in Reference 2, but a deeper realization of the significance of the pulse technique developed in the immediate postwar years.

We are indebted to H. L. Webb for most of the experimental work and our thanks are due to the Directors of the British Thomson-Houston Co., Rugby, England, for permission to describe the results of the investigation.

References

1. See, for instance, *Architectural Acoustics*, V. O. Knudsen, Wiley, New York, 1932.
2. C. A. Mason and J. Moir, "Acoustics of cinema auditoria," *J. Inst. Elec. Engrs. (London)*, vol. 88, part III, pp. 175–190, Sept. 1941.
3. J. Moir, "Reverberation time as an index of room performance," Report of the Physical Society (British) Acoustic Group Meeting, 1947, Physical Society, Prince Consort Gardens, Kensington, London.
4. C. A. Mason, "Interpretation of pulse measurements," Report of the Physical Society (British) Acoustic Group Meeting, 1947, Physical Society, Prince Consort Gardens, Kensington, London.

Notes on Movie Theater Acoustics in Scandinavia

By UNO INGARD

In the Scandinavian countries no fundamental or systematic research on acoustics in movie theaters has been done, as far as I know, and, as a non-authority in the field, I am able to give only a brief informal report of some facts about our theaters and what I think is the general opinion on theater design at the moment in Scandinavia.

NATURALLY most of our theaters are rather small compared with the theaters in this country, seldom with as many as a thousand seats. The theaters are used only for moving pictures and not for other kinds of entertainment, so no attention has to be paid, in acoustic design, to such problems as organ music, for example.

The general design data used, determining the main dimensions of the theater, have been learned almost completely from American experience, with slight modifications here and there. To mention some figures from the design data, we believe the volume per seat should be around 120 cu ft for theaters of ordinary size (about 500 seats). The relation between screen size and viewing distance tends in modern design to be kept below 5, although it lies between 5 and 7 in most older theaters. Other dimensions, mainly determined by visual rather than acoustic conditions, are a ratio of 1 : 1.7 between width and length and 1 : 2.5 between height and width; numbers which I think are about the same as the average used in this country.

The designers are well aware of the importance of avoiding echoes of all kinds. Considerable experience of that sort has been obtained from work of a corrective nature. One notable example of corrective design is the new radio house in Copenhagen in Denmark, where an unusual amount of work was done in order to obtain the most satisfactory acoustics in studios and music halls. One of the most obstinate problems met in this work was the elimination of flutter echoes built up through multiple reflections. Correction was accomplished by changing the shapes of the rooms until the echoes were eliminated. This fact gives an example of the difficulty of predicting the appearance of flutter echoes or long-path echoes from

Presented on June 7, 1949, as part of the Forum on Motion Picture Theater Acoustics, sponsored by the SMPE Atlantic Coast Section and the Acoustical Society of America, held at New York, by Dr. Uno Ingard of Chalmers University, Gothenburg, Sweden, and for the present year at the Acoustics Laboratory, 20B-052, Massachusetts Institute of Technology, Cambridge 39, Mass.

two-dimensional geometrical analysis. The two-dimensional method, however, is used by most of the designers. A great improvement would be made if a three-dimensional simplified descriptive geometrical method could be developed.

We have learned from Mr. Moir (see the preceding paper in this JOURNAL) of a method of studying the echoes in an existing building, but it would certainly also be nice to design an "instrument" for *predicting* the echoes, so they can be avoided from the time the building is in design.

The shapes of the modern theaters are in most cases of the usual type, narrow in the front and wider in the rear part, with a strongly absorbing rear wall. In only two cases I know of, have modern theaters been built without absorption on the rear wall. In one of them, absorption material was put up later in order to reduce disturbing reflections from the wall. The other case seems to have come out all right. It is the Alexandra Theater in Copenhagen, the rear wall of which was made sloping, in order to reflect the sound down to the rear seats. The side walls in this theater are also tilted, 7 degrees inward, the reason being to get some of the sound reflected down to the floor instead of letting it go to the rear wall, where it might give rise to disturbing echoes of some kind. The reverberation time in this theater is rather high, around 1.7 sec at 500 cycles, which is much higher than the average. A theater of the same shape but without balcony has been built in Stockholm, Sweden, but there absorption material was introduced both on the side walls and on the rear wall. Unfortunately, I have had the pleasure of visiting only the theater in Sweden, so I cannot make any statement of comparison. The tilted side walls have been used also for ordinary auditoriums; for example, the new physics lecture hall in Gothenburg.

In regard to the shape of the room, it might be mentioned that the type of floor which is lowest in the middle is beginning to be used in motion picture theaters in Scandinavia. Because it is lowest in the middle and rises toward the rear and front parts of the theater, it is possible to eliminate some of the "neck-strain" for the spectators in the front seats and to make visual obstruction small and almost equal at all parts of the theater.

Even if the volume per seat is kept low, and plane parallel walls, etc., are avoided to get good diffusion, a certain amount of absorbing material of some kind is usually introduced to keep the reverberation time low. As a basic criterion (besides that of uniform and sufficient sound intensity at all seats), we believe that the sound reproduced in the theater should be of the same quality as where the scene was taken, assuming that the sound on the film has the correct reverberation time to begin with. This criterion can, of course, be fulfilled only if the reverberation time is sufficiently low. This criterion is directly connected to the problem of reverberation time for electrically-coupled rooms.

The problem is to find the resulting reverberation time in the reproduction room of a sound which is picked up in a sending room. The sending room and the reproduction room generally have different reverberation times. The combined reverberation time is approximately equal to the longer of the two reverberation times of the sending and reproduction rooms. This is true if the separate reverberation times are not too close. If they are equal, the combined reverberation time in the reproduction room is 20% higher. It may be mentioned that the reverberation curve is not an exponential function in this case, and that the reverberation time is taken as the time required for the intensity to reduce 60 db. If the reverberation is based on, for example, 40 db, the difference mentioned above is larger than 20% which is also the case if the slope of the curve is taken as a base for the definition of reverberation time.

As an illustration, let us assume that a scene has been taken out of doors, where the reverberation time is small. When reproducing this, we cannot get shorter reverberation time than that of the theater, which for low frequencies might go up to about 3 sec. The coordination between reverberation time and the picture shown on the screen under such conditions cannot be satisfactory. I don't know of any systematic studies of this problem, but it would certainly be interesting to learn how we react for a bad consistency of that kind.

The advantage of a short reverberation time is not limited to satisfying the criterion mentioned. There are other advantages, for example, the possibility of obtaining well-defined "sound focus." That this is of importance is established by the results from the survey made by Mason and Moir. In some cases, the theaters were reported unsatisfactory because of the confusing feeling resulting from bad sound focus. Good sound focus might be rather difficult to obtain with a large amount of reverberant energy present. Furthermore, and this may be most important, the possibilities of obtaining disturbing echoes is much reduced. Since we know that it is very difficult to avoid them in the original design, using ordinary design rules, absorption seems to be the safest solution. Another advantage with high absorption is the improved reduction of noise, which I think is of importance.

In order to fulfill the criterion mentioned that the sound shall have the same quality as at the place where it was originally picked up, we must keep the reverberation time almost independent of frequency. By proper choice of absorbers it should be possible to obtain a rather straight characteristic.

The absorption material which is used in the theaters in Scandinavia is mainly thin-panel absorbers for low frequencies and some kind of porous absorber for the highs. The most usual type of porous absorber is tiles of wood fiber. Among the fireproof tiles can be mentioned asbestos and different kinds of gypsum constructions. A very nice method used frequently is asbestos spray. This is very expensive in our country compared with, for example, tiles of wood fiber. There is, however, a great demand for fireproof tiles and I am surprised that tiles of glass fiber, such as used in this country, have not yet been manufactured in Scandinavia. At the present time, when glass or rock wool is used, it is always in connection with perforated facings.

Discussion on the Forum on Motion Picture Theater Acoustics

Members of Discussion Panel:

Leo L. Beranek (Moderator), Massachusetts Institute of Technology
John E. Volkman, RCA Victor
James Y. Dunbar, William J. Scully, Inc.
Richard H. Bolt, Massachusetts Institute of Technology
Edward J. Content, Acoustical Consultant
A. W. Colledge, Western Electric Company
Edward S. Seeley, Altec Service Corporation
Harry F. Olson, RCA Laboratories

Dr. Beranek: To start the discussion, I will call on those at the table, starting at the end:

A. W. Colledge: Not having done any acoustic design work since the late '30's, I can take a more academic and historical viewpoint than some others here.

If this problem were simply the acoustical design of an auditorium, and specifically the theater auditorium, there wouldn't be the difference of opinion that may show up as this discussion gets under way. Our subject might better be defined as how to achieve excellently reproduced speech and music in a theater auditorium with the restrictions imposed on us. We reproduce in the theater both speech and music from a sound track that reflects the acoustics of the sound stage and the electrical characteristics of the recording system, and is affected by the reproducing equipment in the theater.

Also, in talking of the reverberation time of an auditorium, we will have to take into account the "apparent" reverberation time. As an illustration of my point: if you take a long narrow room lined with tile, you will find that the acoustics are terrible. If you place loudspeakers in the ceiling, pointing down and operating at low levels, you will get quite good reproduction as far as the people seated in that room are concerned. So there is something, if you will, in "apparent" reverberation time.

Before the discussion gets under way, I will stick my chin out and say that I feel we, as a group, have gone too far in trying to get too much "liveness" in an auditorium, that is, high reverberation time. I believe there are reasons for that, and probably I can point out some of them.

Initially, our job was only to get reproducing equipment into the theaters. Then acoustics reared its ugly head, and several of the larger companies formed acoustic groups. There wasn't very much known about acoustics before then, and what was known was derived primarily from results obtained in a few theaters. But we suddenly had a few thousand theaters thrown at us.

I still remember that those theaters, which are now considered overly dead,

were the ones where the customers could sit in any seat, relax and understand the performance; and the problem of placing horns was quite simple. However, these theaters were few in number, the large majority were acoustically fair to poor, and something had to be done to them to obtain good reproduction. The only thing to do was to place absorbing material on the rear and side walls and rear ceiling, and you would get at least satisfactory results.

About that time, we suggested tentative reverberation standards and started experimenting with means of measuring reverberation times. We found that the calculated values did not always agree with the measured times. Also, we became conscious of the effects of shape and low-frequency absorption. We found that in theaters that had wood paneling we didn't get the "booming" effect of a high amount of low-frequency reverberation, but instead got quite desirable sound. We began to suspect that a flat reverberation-frequency characteristic was something we would prefer.

But as we got into the shape factors, we began to feel—and I am afraid some hoped—that with nonparallel and broken-up surfaces, we could stand greater reverberation times. Also, I think too much emphasis was placed upon the quality of music reproduction. It is generally agreed that the optimum reverberation times for speech and for music are quite far apart. And something of which we have often lost sight is that about 80% or 90% of all sound coming out of Hollywood is speech.

It seems to me, therefore, that in our consideration of the design of the acoustics of a motion picture auditorium we should be guided by this fact in the compromise that we must make in the reverberation time. We must make this compromise to get good speech reproduction. I feel that, for those theaters that hit such an average, the music reproduction is not at all objectionable.

How far we have gone, I do not know. I am ashamed to say that I can't quote the Academy figures. I do remember, in one theater, using a value of reverberation time of about 1 sec for a volume of 100,000 cu ft. I admit it was not "live," but I don't think it was dead. We never had any complaints on sound quality!

If we have gone too far toward high reverberation times, I think that, as I said before, one of the reasons was the hope that complete breakup of surfaces would allow us to tolerate greater "liveness." It is possible, too, that during the period when higher reverberation times came into use, we made a lot of measurements using a number of horns which were quite directional in the frequency range above several thousand cycles. That is why I introduced the term "apparent liveness." I think it is quite obvious that if we placed the reproducing horns high above the stage and pointed them down into the audience, we had a minimum of side-wall reflections, no ceiling reflections, and those reflections we did get were relatively short. Under these circumstances, we judged that we could tolerate more "liveness." Subsequent to those tests, multiple horns were introduced to give us a dispersion of high frequencies, and the side walls are now back in the picture. There is now a suspicion, at least, that we have gone too far down the trail of "liveness."

Dr. Richard H. Bolt: I am very glad that Art Colledge took the academic point of view. That leaves me free to be quite unacademic. I find that I am in substantial agreement with virtually every point that has been made. Perhaps this isn't a healthy situation for a discussion. I would like, therefore, to pick up just two or three of the points which Mr. Moir and Mr. Ingard have made, and toss out a few comments regarding them.

This question of the first 30-db decay being important is certainly logical, especially when you take Mr. Colledge's

statement that some 90% of footage is speech, and when you add to that the fact that the speech articulation area has a 30-db dynamic range. In no case can a speech component interfere with intelligibility after it has decayed 30-db. Some number such as this seems to make sense in the case of speech. Perhaps it also makes sense in the case of music, though we aren't yet established on a music-articulation engineering curve, as we are on speech intelligibility.

Another interesting point is that this curve of the combined reverberation from two rooms of equal or different reverberation times is quite suggestive. It starts out, as Mr. Ingard pointed out, with a rather small slope, smaller than the final slope.

Now, if again we take just the first 20 or 30 db of the decay, obviously we are talking about a longer "reverberation time," as Mr. Moir implied, than the value defined for 60-db decay.

I believe others have experienced what we have, namely, that when viewing a movie playback, which was originally recorded under one condition of reverberation and played back in a room with a different reverberation time, and when you know roughly what these two reverberation times are, and go through the calculation which Mr. Ingard suggested, you usually get the impression that the combined reverberation is a good bit higher than would be expected from the simple calculation of the combined reverberation from two coupled rooms. Many times it seems more than 20% higher. This feeling, I think, is associated with the first part of the curve. These things all seem to make sense.

I did have one question I wanted to ask Mr. Colledge. When he was discussing the low-level multiple loudspeaker system and mentioned that he got good reproduction, I presume he was referring to the good speech intelligibility, and not necessarily good presence.

Mr. Colledge: That is right.

Dr. Bolt: One of Mr. Moir's points was an interesting one: that there should be no sharp changes in acoustic impedance as you go down the hall. Intuitively, this certainly seems reasonable to me, but I don't quite visualize it in a quantitative way, and I wonder if you have further comments to explain just what you meant? Also, I have another question: You suggest no proscenium arch, and I wonder what led you to make that suggestion.

Also, I would like to support the statements and implications of both Mr. Moir and Mr. Ingard, that the question of proportions for relatively large theaters is probably more a matter of design and pleasing proportions, than of achieving some of the other factors we are looking for. Of course, if with proportions of the "recommended" type we can do a better job of distribution or of avoiding too long delayed echoes, that is fine. The point I wish to bring out here is that in rooms of more than 10,000 or 20,000 cu ft, it does not make sense to talk about the room proportions as providing a smoother distribution of normal frequencies. At low frequencies, in rooms of below 10,000 or 20,000 cu ft, and in small, strictly rectangular rooms, this has meaning. But it is hard to see how it has importance in rooms of 100,000 cu ft.

I would like to conclude with a thought I picked up when I referred back to "home base" on this question of acoustics. That is a healthy thing to do, occasionally: to forget about technical details and check with a somewhat impartial observer: my severest critic who has accompanied me to many theaters. I asked what she thought of the acoustics in a particular theater which I had a hand in designing. She had only one comment.

I might point out that her special interest was dramatics. She taught it, and acted it a good bit, and was quite familiar with the stage. She said, "Don't you realize that movie technique is different from the legitimate theater technique! A good actor on the stage times his speeches to the audience reaction. Now,

if he finds that a certain punch-line is drawing an unusual laugh, he waits for the laughter to die down, and then goes on with his next speech. On the other hand, if you try, in the movies, to design the sequences for the most enthusiastic audience, you will occasionally get a dud of an audience and there will be some gaping holes in the speech. So you have to compromise." She said, "It is true that to some extent this question of audience reaction is built into good movie dialogue, generally by having the punch-line followed by something unimportant. But this isn't carried out 100% in movie technique."

Now, this suggests that audience noise is a good deal more important in a movie theater than in a legitimate theater. I support the thought that, by reducing reverberation time, we gain on this point of noise reduction, as well as on several others that have been brought out.

However, I am not quite convinced that zero reverberation would be good. So far as the quantity, or the magnitude, of reverberation time is concerned, we will agree that combining two rooms produces some such predictable reverberation time. But suppose you are sitting in a dead hall and looking at a picture which is in a reverberant space, so that you expect a lot of reverberation. Maybe it is a politician in a huge convention hall, giving an address, and you record a lot of reverberation. But, if the film or sound is reproduced in the nonreverberant room, all of that reverberant sound is beaming at you from one point. Even though the recorded reverberation time is that which you expect, the effect of that reverberant sound, all coming from one point, is not necessarily the same as if the reverberant sound enveloped you completely.

So you have this conflict, that, for several reasons, we apparently want lower reverberation times than we are used to, though I don't think we want it at zero. Perhaps we should get our absorption by highly concentrated, high-absorption areas, leaving some reflective surfaces all around the room. Then when reverberant sound comes over the sound system, we can feel that some of it is indeed around us, and yet keep the reverberation time low enough for other requirements.

Dr. Beranek: I think we should have Mr. Dunbar speak now and save Dr. Bolt's questions until later.

J. Y. Dunbar: Although much is already known about the simple fundamentals of the acoustics of theaters, I have, during the last six months, encountered a number of theaters and auditoriums, designed by well-known architects, that hark back to exactly what we are sitting under here—the curved ceilings and concave back walls. There is no reason for such design in this country because we have no fire regulations that require it. Theaters are still being as badly designed, acoustically, as possible. Recently, I ran into one that seemed to be deliberately misdesigned. The curvature was exactly right to focus the sound into the middle of the audience. [Laughter] I have also seen theaters in which the balcony extended so far out and so deep that the absorption underneath it made it impossible to hear in the back, even though there was no acoustical treatment under the balcony.

I very much appreciate Mr. Moir's attempt here to evaluate scientifically the contribution of a hall to aesthetics, that is, to the resonance and the timbre of sounds produced in it. I do think that for best response to music, particularly, the hall should contribute a certain amount of quality to what is played in it. I believe that the hall itself is an extension of the musical instruments in the hall, and that it adds to the timbre and resonance of the movie. It is rather a difficult thing to evaluate, but I think it would be a very good approach to try to find out what that contribution is.

I would further like to accentuate Mr. Colledge's plea for deader halls or thea-

ters. In the first place, it means that reverberation is changed very little by changing audiences. The lower the reverberation is when the theater is empty, the less it is going to be changed by adding an audience to it; but if you start out with a high reverberation time, and some of these tests may have been made either in empty halls or partly-occupied halls, you get an entirely different response than you would if you had a full auditorium. If the change in reverberation time is very great, you have a hall that is very bad when there are few people in it, say, at the first show, and excellent at the next show. You get a minimum change in reverberation time with occupancy when perforated seat bottoms are used for sound absorption, or when heavily upholstered seats are used, as in a few of the smaller theaters around the country.

There is one playhouse in New Jersey where the seats are extremely well padded. That is an excellent idea because you can take a nap if the show is dull. [Laughter] In that theater the reverberation is the same whether the house is full or empty.

Another important consideration is the number of cubic feet per person. This number is a function of the number of people entertaining or talking. For example, the smoker in a Pullman car is roughly 6 by 8 feet in area and is a beautiful setting for the raconteur. In a lecture hall that holds up to 50 people, you must provide 70 to 80 cu ft per person. For larger-volume rooms the number of cu ft per person becomes much larger.

The other question is the matter of height. If you increase the volume by increasing the height of the room, you aggravate your reverberation problem; and if you make it too low, then the sound doesn't distribute well in the back and you get peculiar reverberation effects. The ratios of width to length and height of a room are a function of custom that has come down through the ages from the development of public buildings that were more or less pleasing in shape and usefulness. Hence, when we do something peculiar, it shows up immediately.

Edward S. Seeley: I would like to emphasize that we are here challenging the existing recommendations of optimum reverberation time. So far as I know, this is the first time that the established published recommendations have been challenged—certainly the first time since the war, and perhaps since some little time before the war.

I believe that out of this meeting will come a careful reconsideration of the whole question of reverberation time. Certainly it will have to be based upon a great deal of experienced discussion and comment from a large cross section of people interested in this subject. Nothing is going to be settled here this afternoon, I am sure, except that some of us will have convictions renewed, and a few may leave with convictions shaken. I have a feeling that although thinking in architectural acoustics has expanded rapidly in a lot of byways, it is still very strongly dominated by some of the very early conclusions.

One of them, which I will come back to in a moment, is the definition of reverberation time, which has existed unchanged for many years, but which is now being slightly restated. Although people haven't been following the concept of 60 db of decay too closely, they have kept their eyes on that earlier definition, more or less. In most cases, you can't measure more than 30 db of decay outside of the laboratory, and it is doubtful that the ear hears more than the first. I will come back to that in a moment.

Another thing is that the original establishment of optimum reverberation time for rooms was based on unamplified speech. The reverberation time *per se* hurts articulation. However, if the reverberation time of a room is very low and the room is very large, the level of speech will be so low that unamplified speech will be unintelligible in the presence of audience background noise.

Nowadays, we have audio amplifying systems in every large hall, and I question seriously whether this change in the situation has been adequately reflected in practice and in the recommended standards.

I might observe that my own connection is with theaters that are operating—thousands of them, of all kinds. We do not design or treat theaters, but we receive their complaints of bad quality.

I would emphasize that complaints are very rare where the house is too dead. Most of the complaints of poor clarity arise in houses which are on the reverberant side, assuming, of course, that the sound system is not at fault.

I would like to congratulate Mr. Moir and his colleagues in reducing to an engineering basis some of the things we have tried to handle by intuition, "golden ear" experting.

Some of Mr. Moir's illustrations remind me of the significance of direct sound. We recognize the importance of direct sound in theaters, but very little may be found on this subject in the acoustics books. In the theater, as one moves out of the area covered by the speaker—the direct sound area—quality drops rapidly, although the reverberation time is much the same. The ratio of direct to reverberant sound is tremendously important when we are listening to speech.

I am happy that a question has been raised concerning the extent of decay to be represented in an appraisal of the reverberation time. In 1940 and 1941 I tried to sell the idea that we were too interested in the lower end of a decay characteristic. I would like to go further than the gentleman who preceded me and suggest that conclusions be based on the first 14 to 24 db of decay. I would be willing to consider favorably even less than 14 db as I question that trouble is very often experienced with sound that has decayed further than that. I have no evidence to back that up, other than personal observation.

Dr. H. F. Olson: From the foregoing papers and the discussion, it seems that the ratio of direct to reflected sound appears to be the important characteristic in sound motion picture theaters. Fundamentally, this becomes what we might call the effective reverberation, or as Mr. Colledge said, the apparent reverberation.

There appear to be several ways of obtaining a suitable effective reverberation through proper design of the theater. Of course, the shape of the theater is involved, and that is a very complex subject, as has been discussed here this afternoon. The effective reverberation also depends upon the reverberation time of the theater as well as other effects which are more complex and difficult to take into account.

A proper effective reverberation can also be obtained by suitably designed reproducing equipment. For example, the effective reverberation depends upon the directivity pattern of the loudspeakers and the shape of the response-frequency characteristic. Thus, some engineers may work on the theater, others on the equipment, yet both obtain almost the same end results. It is quite true that you can have a very poor theater, yet can obtain very good sound reproduction by the use of suitable equipment. On the other hand, you can have only fair equipment, but a very good theater, and obtain very good sound reproduction.

There is also one other type of theater which is very interesting, namely, the drive-in theater where the reverberation time is very low. In the drive-in theater, the accepted method is to use a separate loudspeaker for each automobile. The reverberation time of an automobile is very low. This system has brought many comments from listeners stating that they feel this type of reproduction is superior to that of the conventional enclosed theater. We have had similar comments from people about automobile radio receivers. Since the war, automobile radios have been improved tre-

mendously, and people tell us that the reproduction in automobiles is far superior to that which is obtained in the home. I believe that the improvement is due to both the characteristics of the receiver as well as the acoustical characteristics of the automobile itself.

From what we have heard today, it seems that the subject of reproduction of sound is still a pretty complex one!

John E. Volkman: I, too, have been very much impressed by the engineering phase of Mr. Moir's paper. It gives a much better way, I believe, of going into the theater and finding out about those acoustical problems which we all admit have been present, but which we haven't been able to analyze well. In a nutshell, I believe that much of the data he has shown emphasizes the fact that echo is as disturbing in the theater as is general reverberation.

What do Mr. Moir's results mean to the architect, and to the person who is going to build the theater? I think this forum emphasizes, as have a number of other forums, that there are still some very important acoustical problems that exist in theaters and that a lot of these problems are echo problems. These echoes arise from a curved rear wall, large expanses of flat areas, flutter echoes, and so on.

Of course, in the sound movie theater, we can eliminate a lot of the echo problems by speaker placement, and by making the speaker directional. If we can get the sound to travel directly to the audience without the beneficial aid of the side walls, so much the better. But no speakers have been designed yet which are so perfectly patterned that they deliver sound only to the audience.

In analyzing the sound arriving at the listener's ear, we have first the direct sound. Then we have the first and beneficial reflections. These are the ones that, as Mr. Moir indicated, come within the first 100 msec.

Beyond that time, come reflections which are, perhaps, second or third reflections. These are the disturbing echo reflections. After that there are the conglomerate reflections which we think of mostly as reverberant sound in the room.

The first 30 db of the decay portion of the curve concerns itself with those early reflections. In this country statements have been made that it is desirable to have the early part of the decay curve drop suddenly, and then the trailing-out reverberation will not be too disturbing from an articulation standpoint, but will add color to the overall sound.

I would like to make a comment also with regard to the reverberation as perceived by the ear when there is a high noise level. In industrial plants, we have observed that with the noise in the plants we are not conscious of reverberation in the overall system. The same applies in those types of systems that have the multiple-speaker arrangement, which Mr. Colledge mentioned. However, if you stop the machinery and then listen to the sound, the reverberation sounds terrific; but you are not conscious of it when there is intense noise. So I think we are all agreed that those last reflections that are more than 30 db down, are not of prime importance.

There has been some discussion as to whether our optimum reverberation time is right, too high or too low. I don't think we are going to change that very much. The ear will tolerate considerable variation, but it dislikes some of these disturbing echoes that get to the audience.

I think I agree with the other speakers that the shape factor—that is, the proportions—in the large room is not dictated so much by the acoustics as by other more general considerations of appearance, and so on, because the eigen tones [natural frequencies] and the room resonance are very close together, and are not predominant at the higher frequencies.

E. J. Content: I think we are up against the same old problem that we have been fighting for a number of years—what is high-quality reproduction? Frequency response, we know, is only one factor. There are many other factors in the electric system which have been pretty well licked by now, such as signal-to-noise ratios and distortion in the electrical circuits. Those, I think, we can discount and take out of the picture entirely. However, the acoustical distortions are the ones that we are more interested in, and they consist mainly of echoes and interference patterns.

Mr. Moir stated that the worst theater he had studied also had the best frequency characteristic. I am wondering what he meant when he said it had the best frequency characteristic. Do we know what frequency response the ear likes best to hear? I think it is high time that we or the Society of Motion Picture Engineers, or someone, begins some kind of studies in the psychology of ear-hearing to determine what the ear likes to hear.

You can have a flat loudspeaker in a relatively large auditorium, and may find it sounds perfect; but if you put that same reproducer in a small room, it sounds as though there are too many high frequencies in its output. That, of course, is a function of the attenuation of sound in the air. When you have a large auditorium, where the mean free path is large, you have much greater attenuation of the higher frequencies, especially in locations where the humidity is very low at times.

Now, let us go back to frequency response of a room. The frequency response, or frequency characteristic of the room is determined by the absorption of the different sounds by two means: one, by the acoustical surfaces; and the other, by the attenuation through the air. For a small theater to have the same response, much more absorption of the higher tones is needed than for a large theater. I am talking of the 1000-seat house, as against a 3500-seat one, because the length of a mean free path is much greater in the large house.

If the reflected tones from the room surfaces and the tones from the loudspeaker have been attenuated to such an extent that they don't represent the same true character of tone that the loudspeakers emit, naturally it is much more pleasant to listen to the loudspeakers without any reverberation. However, if the absorption of the theater can be adjusted so that the reflected tones give you the same response as the original sound, considerably more reverberation can be tolerated than otherwise. That is one reason why, when you get out of the beam of a loudspeaker, the tone goes to pieces. It is because the absorbing surfaces do not reflect the same tones that are cast upon them; otherwise, you would get the same tone color reproduced.

Dr. Beranek [after thanking the panel speakers]: Mr. Moir has, I think, at least three questions to answer. I have been keeping track of them. He is supposed to answer: Why no proscenium arch? Why no sharp changes in peaks? And what is the best sound system characteristic?

Mr. Moir: The first two questions really cover two aspects of the same problem, that of maintaining a smooth flow of sound energy along the hall. Experience in many cinemas has indicated that changes in sound level and sound quality are often associated with sharp changes in the cross section of the hall, of which two examples are the proscenium arch and the stadium-type of design. While no quantitative data on the adverse effects are available, a typical example could be quoted. A legitimate theater of modern design was the subject of serious criticism on the score of lack of intelligibility, until an apron stage extending forward of the proscenium arch and over the orchestra was constructed. As an ordinary member of the audience, the speaker had on many occasions noted the improvement

in intelligibility as an actor moved down stage past the proscenium arch.

Regarding the best sound system characteristic, I have checked my idea of "best" in many British theaters and found that it did not differ appreciably from the published American data. In particular, a roll-off above 2.5 to 3 kc has seemed essential for acceptability. Anything flat to 5 or 6 kc has been found intolerable.

Dr. Beranek: Are there other questions for Mr. Moir or other discussion?

Mr. Volkman: We have made somewhat similar measurements in the overall acoustic response. Some of the installations that sound good were measured by the warble-frequency method. Incidentally, one of the nice features of Mr. Moir's method of measurement is that it simulates the short-pulse effect of speech.

Going back to this response, we have found that a flat response up to 3200 cycles which tapers off about 12 db per octave is preferred. In recording, they more or less raise the overall acoustic response at the top end.

Mr. Colledge: It is pretty close to the Academy curve. Has your experience indicated that for typical public address systems' sound reinforcement, you can use more highs?

Mr. Volkman: Yes.

Mr. Colledge: I find that on stereophonic systems I can run to 1000, and then start tapering off.

Mr. Moir: The experience we had confirms your experience there.

Mr. Volkman: But this does not show, of course, what your method shows, that your direct response may be rising, and your reflected response falling.

Mr. Moir: Our work on frequency characteristics has given results of the same kind.

Anon: Mr. Seeley pointed out that we are here challenging the accepted techniques of theater design. In order to make a satisfactory challenge, we must cumulate a lot more experience. It seems worth while, therefore, to disseminate among the group here, at least, some of the details of technique that you have worked out, so that we can benefit in getting experience of our own. A question that occurs to me is how do you avoid the transient that normally occurs when you turn a signal on and off? Do you have some control over that?

Mr. Moir: It is a problem, but a double contact switch can be used to close the circuit through a resistance, and then to short out the resistance.

Anon: Do you find that this mechanical arrangement is satisfactory?

Mr. Moir: We have gone no further than trying this arrangement. There are two or three other more important problems on which we are doing some work.

Anon: On your pictures, I noticed there was no peak—no initial pulse. Was that because the picture didn't show it, or was it because it wasn't there?

Mr. Moir: Do you mean the click?

Anon: Yes.

Mr. Moir: No, there was no serious click on the picture. There is no reason why it should be above the noise level in the theater. If you listen to the pulse, there is a slight click, but it does not appear to be appreciable. We think that it can be neglected.

Anon: Do you have any idea about what could be used as a quantitative measure of the ratio of direct-to-reverberating sound? Would you integrate the area under the reverberation curve up to a certain value of time?

Mr. Moir: I don't really know. We haven't done enough work to make a definite statement. We haven't really had enough experience to formulate any definite proposals. That is a weakness of the position as it is at present. It needs to be figured, but just at the present time we are in a depression in England, and there is no money for development. It is regrettable.

Anon: One other question: Have you tried varying the frequency of the test oscillator, more or less continuously?

Mr. Moir: We have taken pictures of

pulses of tone over the whole frequency range.

Anon: What I meant was, do you get a continuous variation as the frequency is changed?

Mr. Moir: One of the methods we developed was to try to take frequency characteristics in a very short time, of the order of 0.1 or 0.2 sec, but it revealed nothing and we dropped it.

*Ben Schlanger:** As an architect, one point that bothers me today is that, in the case of a motion picture theater, we have a very special type of auditorium which is different from the theater, where there is simply no reinforcement, and also a theater where there might even be reinforcement, such as a public address system.

For many years, now, motion picture theaters have had sound reproduction that we might call commercially acceptable, but we are coming to a new age in motion picture theater experience, in which the dramatic impact is going to be the thing. In other words, we have to go beyond the point of what is just acceptable—on such aspects as audibility, intelligibility, and so on.

What it all boils down to is this: Is it possible for the acoustical color that is added by the room itself to be completely discounted so that whatever effect was made in the production could be delivered to the audience without coloration by the room?

Will a dual system of horns be effective—one set, which may be behind the screen, for the dialogue, where reverberation isn't important—and the other set scattered around the room where an effective reverberation is required to give, dramatically, the effect desired?

As architects, we have always been told by the acoustical engineers that the shape of the room and the amount of reverberation, and so forth, are important. I wonder if we aren't past that stage. I noted that Mr. Ingard said they are going to less than 5 in the relationship of the screen width to viewing distances. That is an important point. I can safely predict that is true. It is going to go far below 5. I think people are going to sit closer to the picture. The picture is going to dominate your field of vision.

I think we have a whole new set of principles to work on, because the motion picture is no longer the novelty, at least the sound motion picture, that it was 20 years ago. Today it is dramatic impact, size of picture and realistic delivery that have become important, because home television has become a real competitor.

I have been very much interested in what was delivered here. I think you are really making progress, but I feel you have to give prime consideration to the ultimate aim, and that is more effective delivery of both the visual and aural storytelling.

Mr. Moir: I think some of the engineers here might reply to these points better than I. I know of no method of giving you open-air experience in an enclosure, for various well-known reasons. I think you may be right when you say you should move along those lines, but I would like to tackle some of the problems that are easier than that.

Mr. Seeley: I feel that the relationship you found between frequency characteristic and quality is an effect and not a cause, possibly. You probably selected frequency characteristics most successful in the house, and then you later made measurements and found out what those characteristics were. It does not mean that the characteristic that slopes off quickly or remotely is a good one, but is something that reflects some characteristic or quality of the house.

Dr. Bolt: I don't believe that this point has been brought up as yet, but it certainly is an important one: the question of the proper adjustment of level in the theater. We had occasion recently

* Partner, Schlanger and Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53rd St., New York 19.

to make measurements continually during the performances in a theater at various points, not only to listen, but to overhear comments of people watching the show and the people who came out from the show. There was a relatively small level difference which separated good from bad.

In this particular case, when we were running around an 80- to 85-db average, the reactions expressed after the show indicated that that was too loud. We had control over the level in this theater during the performance. When we got it down to about a 60-db average on the speech, we were missing a good bit of the intelligibility. Then we heard a conversation behind us, where a girl and a boy who were enjoying the show, said, "Gee, can you hear that very well? Something must be wrong." That was at 60. Between 65 and 70 the level was satisfactory.

The significant thing that came out of measurement of this kind was that not more than 15 db separates pretty bad from pretty good. I wonder if this is the sort of experience found by the others?

Mr. Moir: Yes. The BBC published some figures on level preference tests. I have the papers in my bag and will show you the figures. They found, surprisingly, that the engineers preferred a higher level than the public, and older people preferred it slightly lower in level than young people.

Mr. Volkman: You described the one case where the listening conditions were good in some parts of the auditorium, and poor in other parts. How highly localized were the poor listening areas in the theater? Do you have some information on that?

The reason I ask is that we had a similar problem in the Radio City Music Hall about ten years ago when we used frequency pulses to measure the echo and help us locate the echo. We found it to be due to the columns supporting the mezzanines just at the rear of the orchestra seating area, and they had to be inclined forward. The total area affected by those columns was very minor, and the echo was only in the rear of the auditorium. When we inclined them, we got rid of it. How localized was that?

Mr. Moir: In that case, I showed a slide. It was over 4 seats.

*W. F. Jordan:** It has been said that the acoustics problem must be carried all the way through to the recording. If I recall correctly, back when sound pictures first started, the recording characteristics were changed in a very radical manner, in order to adapt the sound to the then existing theater conditions. Now, as architectural improvements are made, we are going to have to revise our original concept of a recording characteristic. In other words, the so-called Academy characteristic, a large rise in the high-frequency response, may have to be modified.

[Moderator Beranek adjourned the meeting.]

---

* Movietonews, 460 W. 54th St., New York 19, N.Y.

New American Standard

Sound Transmission of Theater Projection Screens, PH22.82, was developed by the Society's Sound Committee based on a war standard, Z52.44-1945. The specified transmission characteristics are in accord with most present-day theater screens of proven performance value.

The need for this standard was indicated by the occasional installation of screens with excessive transmission loss. Increasing the gain of the sound system as a compensation very often drives the amplifier into its nonlinear region and consequently produces excessive distortion.

American Standard for

Sound Transmission of Perforated Projection Screens

ASA Reg. U. S. Pat. Off.
PH22.82-1951

*UDC 778.554.4

1. Sound Transmission Characteristics

1.1 The sound transmission characteristics of perforated projection screens shall be such that the attenuation at 6000 cycles, with respect to 1000 cycles, is not more than 2½ db and the attenuation at 10,000 cycles, with respect to 1000 cycles, is not more than 4 db. The regularity of response shall be such that there is no variation greater than ±2 db from a smooth curve at any frequency between 300 and 10,000 cycles. The general attenuation at and below 1000 cycles should be not greater than 1 db.

2. Method of Measurement

2.1 The sound transmission of the screen shall be measured by means of a loudspeaker, fed by an audio oscillator and amplifier, behind the screen, and a calibrated microphone, amplifier, and output meter in front of the screen. The loudspeaker shall be of the type normally used in motion picture theaters for the size of screen being tested, and shall be placed with its axis not less than 2 feet from an edge of the screen with its mouth parallel to and separated from the screen by 4 to 8 inches (center cell in the case of a curved-front multicellular horn). The microphone shall be located 10 to 12 feet in front of the screen and on the axis of the loudspeaker. The sound transmission of the screen at any frequency is then the difference in the sound level measured with the screen in place and with the screen removed.

2.2 Suitable precautions shall be taken to eliminate or minimize the effect of standing waves in the test room.

Approved July 17, 1951, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

70th Convention

Hollywood Roosevelt Hotel, Hollywood, Calif., October 15–19, 1951

Color Processes of motion picture photography and release printing now being introduced commercially are capturing the interest of all motion picture producers and film laboratories. Latest developments along these lines will be presented for the first time at one of the eleven convention sessions. Related to these current indications of progress in the field of "color" is the continuing work of the SMPTE Color Committee which will be reported upon by Chairman H. H. Duerr.

Color Aspects of television have been in the public eye recently and, in addition to popular concern for the future of commercial color television, there has been serious interest among technical people. Examples of the most pressing questions are requirements of studio conversion to color standards, and an estimate of those factors now apparent that will some day prove to have had a significant influence over long-term growth. Both will be discussed at length during another session, along with the description of a new system for reproducing a color television picture.

Magnetic Recording equipment newly developed for efficient re-recording of feature film sound as well as numerous improvements in equipment and production techniques will be reported upon over two technical sessions.

High-Speed Photography as a tool in aircraft, guided missile and ballistics research will be the subject of one convention session. Another will include papers on new developments in cameras and on sound recording as a data gathering process.

Stereo-Projection, much conjectured about, will be discussed, demonstrated and explained. This session which is certain to interest motion picture people widely is scheduled to include reports by two SMPTE engineering committees, one on Picture Flicker and one on Screen Brightness.

Chairman of the Pacific Coast Section, C. R. Daily, is also *Local Arrangements* Chairman for the fall convention. This latter title gives him the pre-convention responsibility for lining up the three sessions to be held away from the Hotel and for the general supervision of all arrangements except in connection with ladies' program, papers, motion picture short subjects, luncheon and banquet. He will keep an eye on:

Hotel Reservations and Transportation which Bill Kunzmann has assigned to Vaughn C. Shaner.

Projection Facilities, at all four meeting places, Hollywood Roosevelt Hotel Blossom Room, Academy Award Theater, Republic Studio Scoring Stage and Columbia Square. Emery Huse, Eastman Kodak Company, will provide the 16-mm arc equipment for use at the hotel. Members of Los Angeles Projectionists Local 150 will put the pictures on the screen.

Public Address equipment and the recorder used to take down technical discussion will be supplied by SMPTE headquarters and operation will be supervised by E. W. Templin, Westrex Corporation.

Engineering Activities

Color The Color Committee, under the Chairmanship of Dr. Duerr, met in New York in mid-June. Most of the Committee's work is done by Subcommittees; therefore the meeting opened with reports of Subcommittee Chairmen:

(a) Color Symposium Subcommittee: Lloyd Varden indicated that additional information is still required before editorial work on publication of all color-process data can begin. Both DuPont and Ansco have proferred assistance along

these lines, and a draft of the introductory report should be ready shortly.

(b) Subcommittee on Projection Light Sources and Screens for Color Film: Ronald Bingham discussed the status of the several projects. A good deal of information has been acquired on the effect of theater projection practices upon color quality and a report will soon be available. Characteristics of projection screens are also under study and a report is now being prepared by Mr. Gillon.

(c) Subcommittee on Spectral Energy Distribution of Photographic Illuminants: Monroe Sweet stated that the Subcommittee had met on March 9, 1951, and had agreed that the aim of this group was "to prepare a report of the history, present status and, if possible, a proposal for improved methods of determining, and technology for specifying, the spectral energy distribution of photographic illuminants, particularly those used for motion picture photography." While in an early stage, progress is being made on this project.

Dr. Duerr then reported that a request had been received to standardize the color temperature for color films used with tungsten light sources. The technical and commercial aspects of this problem were discussed and it was agreed that this matter properly belongs within the scope of the Motion Picture Studio Lighting Committee as far as motion picture technique is concerned, and within the scope of the ASA Sectional Committee, PH22, as far as the amateur and professional color films are concerned. The Color Committee would provide assistance to the Studio Lighting Committee if needed.

The Committee's part in the Society's Glossary project was the last point on the agenda. After much discussion, it was agreed to set up a preliminary subcommittee whose function would be merely to determine which terms should be included in the Glossary. When this is completed a more formal committee could be established to work on the definition of terms.

Laboratory Practice At its last meeting during the 69th Convention in New York, the Laboratory Practice Committee took definite action on two projects:

1. A Subcommittee to initiate a standard on laboratory review-room screen brightness is to be formed under the chairmanship of Edward Cantor.

2. It was agreed to ballot the entire Committee on the "Proposed American Standard for 16-Mm Optical Printer Aperture for Enlargement Printing to 35-Mm." Gordon Chambers was commended by the group for his efforts in preparing the recommendations upon which the proposal is based. The ballot is now almost completed and in all likelihood will be approved and forwarded to the Standards Committee.

Screen Brightness In accordance with ASA's procedure of periodically reviewing American Standards, the Screen Brightness Committee is now taking a letter ballot on "Review of American Standard Z22.39-1944, Screen Brightness for 35-Mm Motion Pictures." The Standard, as presently worded, applies to all theaters. Outdoor theaters rarely achieve the minimum value of screen brightness as set by the Standard, and so as a practical matter there has been some talk of limiting the Standard to indoor theaters. This question is included in the letter ballot.

Standards For the last several months the Standards Committee has been balloting on a whole series of proposals; some, on the question of the approval of preliminary publication and others, whose preliminary consideration has been completed, on the question of submitting to ASA for processing as an American Standard. These are:

Preliminary Publication

Proposed Standard for Aperture Calibration of Motion Picture Lenses.

Submission to ASA

1. Dimensions for Projection Lamps—Medium Prefocus Ring Double-Contact Base-Up Type for 16- & 8-Mm Motion Picture Projectors, PH22.84.
2. Dimensions for Projection Lamps—Medium Prefocus Base-Down Type for 16- & 8-Mm Motion Picture Projectors, PH22.85.

3. Splices for 16-Mm Motion Picture Films for Projection, PH22.24.
4. Splices for 8-Mm Motion Picture Film, PH22.77.

Recently Approved

Preliminary Publication—Proposed Standard for Cutting & Perforating Dimensions for 35-Mm Film (to be published in a forthcoming issue).

Submission to ASA—Edge Numbering of 16-Mm Motion Picture Film, PH22.83, and 16-Mm Motion Picture Projection Reels, PH22.11.

Television Studio Lighting The Television Studio Lighting Committee met on June 20th in New York City. Unfortunately, the attendance was so small that it was impossible to make decisions representative of the thinking of a cross section of the television industry. The Chairman, Mr. Richard Blount, noted that while it might be difficult for those members outside of New York to attend meetings, he would welcome their written comments which would be of considerable value in directing the thoughts of the Committee.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 **Membership Directory**.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Aye, Thomas L., Radio Engineer, Henry J. Geist & Associates, Inc. **Mail:** 42 Middle Neck Rd., Roslyn, Long Island, N.Y. (**A**)

Barstow, John M., Telephone Engineer, Bell Telephone Laboratories. **Mail:** 105 Intervale Rd., Mountain Lakes, N.J. (**M**)

Barz, Helmut, Head, Rawstock and Printing, High Commissioner for Germany. **Mail:** Astallerstr. 15, Muenchen, Germany. (**M**)

Bhate, Arvind G., Development Engineer, National Carbon Co. (India), Ltd., P.O. Box 2170, Calcutta 1, West Bengal. (**M**)

Brown, Ilo M., Chief Engineer, The Ballantyne Co. **Mail:** 1707 Davenport St., Omaha, Nebr. (**M**)

Chodkowski, Stanley, New Inst. for Film and Television. **Mail:** 19 Goodyear Ave., Buffalo 11, N.Y. (**S**)

Chyka, George W., Motion Picture Cameraman, KOTV—Cameron Television. **Mail:** 1320 S. Boulder, Tulsa, Okla. (**A**)

Cooper, Donald H., Engineer-In-Charge, National Broadcasting Co. **Mail:** 14 E. Mason Ave., Alexandria, Va. (**A**)

Dickinson, Robert V. C., Recording Engineer, Telescriptions, Inc. **Mail:** Roome Rd., Towaco, N.J. (**A**)

Fields, Louis, Photographic Technician, Institute for Medical Research. **Mail:** 4024 Stone Canyon, Sherman Oaks, Calif. (**A**)

Filipowsky, Richard F. J., Professor of Electronics, Head of Faculty, Madras Institute of Technology (MIT India), Chromepet, Chingelput Dt., So. India(**A**)

Frierson, Leland G., Vice-President, Ruthrauff & Ryan, Inc. **Mail:** 108 E. 86 St., New York 28, N.Y. (**M**)

Frisbie, H. E., District Service Manager, RCA Service Co. **Mail:** 9215 Fernhill, Parma, Ohio. (**M**)

Geist, Henry J., Sales Engineer & Consultant, Henry J. Geist & Associates, Inc. **Mail:** 196—5th St., Stamford, Conn. (**M**)

Glasser, Donald W., Photographic & Reproduction Technician, Westinghouse Research Laboratories. **Mail:** 853 Inwood St., Pittsburgh 8, Pa. (**A**)

Haraughty, Lois E., Chemist, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood, Calif. (**A**)

Hayden, Edward J., Chief Electrician, Ace Film Laboratories, Inc. **Mail:** 120 Linwood Ave., Bellmore, Long Island, N.Y. (**A**)

Heidt, Horace, Producer, Director, Actor. **Mail:** 14155 Magnolia Blvd., Van Nuys, Calif. (**M**)

Kantrowitz, Philip, Electronics Engineering Research Assistant, Microwave Research Laboratories. **Mail:** 2435 Frisby Ave., Bronx 61, N.Y. (**A**)

Kapur, Jit L., University of Southern California. **Mail:** 1023 W. 36 St., Los Angeles, Calif. (**S**)

Lankester, Christopher H., Technical Supervisor, United Nations. **Mail:** 144–79 Grand Central Pkwy., Jamaica 2, N.Y. (**M**)

LaSala, Frank A., Foreman, Cameraflex Corp. **Mail:** 185 Forbell St., Brooklyn, N.Y. **(A)**

Madsen, Erik R., Chief Engineer, Bang & Olufsen Aktieselskab. **Mail:** Gimsinghøje, Struer, Denmark. **(M)**

Mayer, Allan, Engineer, General Precision Laboratory. **Mail:** 132 Huntville Rd., Katonah, N.Y. **(M)**

Mayer, George H., Lighting Carbon Specialist, National Carbon Div. **Mail:** 6207 Park Lane, Dallas, Tex. **(M)**

Nash, Charles Kevin, University of Southern California. **Mail:** 800 Sunset Ave., Venice, Calif. **(S)**

Pieroth, John Phillip, Jr., Photographer. **Mail:** 1609 Peach Court, Seattle, Wash. **(A)**

Richman, Donald, Television Engineer, Hazeltine Corp. **Mail:** 64-25F 186 Lane, Fresh Meadows, N.Y. **(M)**

Riebel, Fred, III, Supervisor, Motion Picture Bureau, AEtna Life Affiliated Companies. **Mail:** 151 Farmington Ave., Hartford, Conn. **(M)**

Rothschild, Richard S., Engineer, Allen B. Du Mont Laboratories, Inc. **Mail:** 1165 Park Ave., New York 28, N.Y. **(A)**

Schwartz, Morton, Film Recording, RCA Victor Div. **Mail:** 698 West End Ave., New York 25, N.Y. **(A)**

Sheldon, Stewart, President, Sheldon Theater Supply. **Mail:** 1415 Amberly Dr., Dayton, Ohio. **(M)**

Sims, John M., Commercial Manager, Motion Picture Equipment, General Precision Laboratory, Inc. **Mail:** Manville La., Pleasantville, N.Y. **(M)**

Spiller, Gino, University of Southern California. **Mail:** 713¾ W. 35 Pl., Los Angeles 7, Calif. **(S)**

Tall, Joel, Audio Engineer, Tape Editor, Columbia Broadcasting System. **Mail:** 1594 Unionport Rd., New York 62, N.Y. **(A)**

Tohill, James C., Quality Control Analyst, Du-Art Film Laboratories, Inc. **Mail:** 37-42 64 St., Woodside, Long Island, N.Y. **(M)**

Torp, Richard V., Photographer & Color Technician, Technicolor Motion Picture Corp., Research Dept., 6311 Romaine, Hollywood 38, Calif. **(A)**

Wentker, Fred W., District Service Manager (Chicago District), RCA Service Co. **Mail:** 1505 Oak Ave., Evanston, Ill. **(M)**

White, Reginald A., Engineer, General Precision Laboratory, Inc. **Mail:** 94 Park Rd., Deepwood, Chappaqua, N.Y. **(A)**

CHANGE OF GRADE

Ballantyne, Robert S., President, Ballantyne Co. **Mail:** 1707 Davenport St., Omaha, Nebr. **(A)** to **(M)**

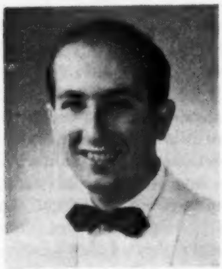
Mitchell, Wayne, Photography Instructor, Cinematographer, Audio-Visual Center, Miami University, Oxford, Ohio. **(S)** to **(A)**

Montague, Henry B., Projection Engineer, EUCOM Motion Picture Service, Maintenance & Supply Section, APO 807, c/o Postmaster, New York, N.Y. **(A)** to **(M)**

DECEASED

Hornstein, Joe, President, Joe Hornstein, Inc., 630 Ninth Ave., New York 19, N.Y. **(A)**

Newell, David A., Recording Supervisor, Samuel Goldwyn Studios. **Mail:** 1156 N. Poinsettia Pl., Hollywood 46, Calif. **(M)**



Donald Stern

Arthur Schneider

Donald Stern and Arthur Schneider in the early spring were elected next year's Chairman and Secretary-Treasurer, respectively, of the Society's Student Chapter at the University of Southern California. Photos are by courtesy of University Photographer, University of Southern California.

Carl Louis Gregory

The full and active life of Carl Louis Gregory, pioneer cinematographer, came to an end at the age of 68, last March in Van Nuys, Calif., after a year's illness of arteriosclerosis.

The man who was to receive many honors, be granted many patents, to teach and lecture widely, to pioneer in many parts of the motion picture field, was born in Walnut, Kan., in 1882. At the age of 11 he was making his own first camera from a cigar box and spectacle lenses. He entered Ohio State University in 1899, became a graduate pharmacist in 1902 and was graduated in 1904 with a B.Sc. in Chemistry. He earned money for his college courses by doing the photographic work for the college annual and biological photography for the medical and veterinary colleges.

After college began a career which for many years was to bring some new activity every year, sometimes with every change of season:

In mid-1904 he joined the Official Photographic Dept. of the Louisiana Purchase Exposition and was in charge of various sections including one where up to 1200 individual portraits were taken in a day, the airdrome section with airship, balloon and aerostatic work for newspapers and publicity, and the Quick Post Card Galleries which took photos and finished them in seven minutes.

In 1905 he was taking views for post card and commercial reproductions in the Southwest and Old Mexico, with a studio at Monterrey, Nuevo Leon, Mexico. In the spring of 1906 he had a commercial photography gallery at San Antonio, Texas, in conjunction with the Mills Engraving Co., and was making wet-plate line and halftone negatives for Mills. During the summer of 1906 he was official photographer for Manitou & Pikes Peak Ry. That winter he was in charge of the photographic Laboratory of Dodd-Rogers Co., Cleveland, Ohio, doing amateur finishing, blue printing and commercial photography.

In the spring of 1907 he was appointed photographer with the U.S. Geological Survey, doing chiefly wet-plate work but also lens and shutter testing and photomicrographic work under polarized light. In 1908 he transferred to the U.S. Reclamation Service, having first to do with everything in the making and exhibition of lantern slides then taking, developing, printing, titling and assembling motion pictures of the Reclamation Service work. He was then also installing, wiring up and operating stereopticons and motion picture projection machines to accompany lecturers. That year he lectured on color photography at George Washington University and before the American Chemical Society.

In the winter of 1908–9 he was stage manager and photographer for Burr McIntosh who gave lectures on "Our Country," "Our Navy," "Our Island Possessions," etc., in the major cities of eastern United States. In the spring of 1909 he began photographic investigation in cinematography for Thomas A. Edison.

In 1910 he became Chief Photographer for the Thanhouser Film Co. and in 1911–12 built for Thanhouser the California Studio which was later used by Majestic, Reliance and Chaplin film companies. In 1912 he was chief photographer and often director of a large number of scenic, educational, dramatic and propaganda films. In 1913 he was in charge of the entire production of the Princess Brand Films for Thanhouser, combining direction and photography of such films as *Break Upon the Waters*, *The Little Church Around the Corner*,

Her Right to Happiness, The Tangled Cat, Friday the Thirteenth, Her Way, A Shotgun Cupid, The Grand Passion, The Strike, The Campaign Manageress, The Mystery of the Haunted Hotel, The Water Cure, A Deep Sea Liar, Little Brother, and many others featuring such stars as William Russell, Florence LaBadie, James Cruze, Margaret Snow, Muriel Ostrich, Mignon Anderson and John Lehnberg.

He was the cameraman on the first serial, *Million Dollar Mystery*, starring Margaret Snow.

In the winter of 1914 he was Chief Photographer for the Williamson Submarine Expedition to the West Indies. On that expedition he made the first motion pictures ever taken beneath the surface of the ocean, something which was a large factor in his being made a Fellow of the Royal Photographic Society of Great Britain in 1915.

In the summer after returning from the West Indies he took a troop of actors on a western trip making dramatic and scenic pictures in the national parks under the permission and indorsement of the Secretary of the Interior. That fall he lectured at the Smithsonian Institution, Museum of Natural History at New York, the Philosophical Society at Philadelphia, and others.

In 1915 he was engaged in photographic research for Technicolor with Prof. E. J. Wall at Massachusetts Institute of Technology, then in the years 1916 and 1917 successively was Chief Photographer for Henry W. Savage Motion Picture Productions and Annette Kellerman Co., Fox Pictures. In 1918 he was in charge of instruction at the U.S. Signal Corps School of Cinematography where 800 men were trained for overseas photographic units. In 1919 he was lecturing on photoplay making at Columbia University. Over 200 reels of instructional film were produced by him in 1920–21 for the Graphic Instructor, subsidiary of United Publishing Co. which used the films for department store training.

During the next year he was doing photographic and research work for the Rodman Wanamaker Indian Foundation and producing such films as *The Vanishing American, Marshal Foch's Visit to America* and *Indian Customs.* In 1922–23 he was Managing Director of the Orient and India Picture Corp., producing films from his own scenarios in the South Seas, Japan, China, Malaya, Burma and India. In 1924–28 he was Dean of the New York Institute of Photography, during which he wrote one of his books on motion picture photography which is now reported on the rare book lists. In 1928 he was technical correspondent and in charge of professional equipment sales for Bell & Howell. From 1929 until 1936 he was occupied as consultant on photographic and cine processes and patents, serving such clients as Terrytoons, Fox, Pathescope, Metro, Paramount, Universal, Eastman Kodak, Raycol of London, Societe Francais Cinechromatique of Paris, and Siemens & Halske of Berlin, holders of patents on the lenticular film color process which the Kislyn Corp. has owned in this country. In 1936 he became Assistant in charge of Motion Picture, Photographic and Sound Record Surveys at the National Archives in Washington, D.C., where he remained until 1946.

He was a member of this Society and was also a member of the American Society of Cinematographers, the Edison Pioneers and the Oval Table Society. He was credited with building the first optical printer and he designed many machines such as a combined micro-colorimeter and densitometer, disk recording machine, a machine for cleaning dirty or oily film, for color processes as well as for cartoon animation on which he had patents. He had been a frequent contributor to this *Journal*, as well as to many other periodicals. He had for several years been editor of the department "Motion Picture Photography" in *Moving Picture World* and had also for years edited "Amateur Cinematography" in *Camera Magazine.*

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were Published in the April *Journal.*

Fred Schmid

After 53 years of service with the C. P. Goerz American Optical Co., New York, President and General Manager Fred Schmid has resigned from active work and is now living in retirement at his home in Larchmont, N.Y.

It was on September 13, 1898, when Fred Schmid's destiny was tied up with the Goerz interests. On that day, Fred Schmid, a young instrument-maker, applied for a position with the Goerz Optical Works in Berlin-Friedenau, Germany. After a few hours' interview with C. P. Goerz, the founder of the Goerz enterprises, the latter offered to send him to America to open a branch factory there, in order to meet the ever increasing demand for Goerz photographic lenses in the U.S.A. In a spirit of adventure young Schmid accepted the offer readily and, after six months of intensive study of the manufacturing methods of the parent house, he arrived in New York in May 1899 to set up shop. Since then the making of Goerz American photo-lenses was carried on here under his personal supervision.

The *American* firm was incorporated in 1906 as the C. P. Goerz American Optical Company and its assets and manufacturing rights were acquired through purchase by a small group of American citizens in 1920. The *German* Goerz Company was merged in 1926 with the well-known Zeiss Ikon Corp. in Germany. Today the *American* Goerz firm is the only company which supplies a full line of the Goerz Photo-lenses.

Fred Schmid, at first in charge of production, was made General Manager in 1910, Vice-President of the American company in 1920 and finally President in 1937. He made the last of his frequent business trips back to Germany during the summer of 1949. The company has announced that Mr. Schmid will continue to serve on its Board of Directors and in a consulting capacity.

Fred Schmid was born at Lehe, near Bremerhaven, on August 5, 1870, and next month will celebrate his 81st birthday with his three daughters at their summer cottage in South Salem, N.Y. He has been a member of this Society since 1929.

BOOK REVIEWS

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses

By John F. Rider and Seymour D. Uslan. Published (1950) by John F. Rider Publisher, Inc., 480 Canal St., New York 13. 992 pp. + 8 pp. index + 3000 diagrams and illustrations. $8^1/_2 \times 11$ in. Price $9.00.

This valuable new book is a rather complete collection of practical information relating to modern oscillographs and their uses. There is the absolute minimum of mathematics included, and the authors have not resorted to too intense theoretical treatment. Only the essentials have been covered. Since the book is on a practical level it will undoubtedly find widespread acceptance.

The reader will find a description of practically every type of commercial oscillographic equipment included, together with information which the engineer can put to practical use every day.

As a matter of fact, there are 331 pp. devoted exclusively to instruments and accessory equipment. This rather complete coverage, in itself, will make the book extremely useful.

Cathode-ray tubes are fully covered in some 171 pp. Over 200 pp. are devoted to specific applications of oscillographs, and 107 pp. to circuit diagrams and various operating specifications. There is a complete bibliography at the conclusion of each chapter which will prove very valuable to the engineer for reference purposes.

The 1580 illustrations showing photographic reproductions of various waveforms will unquestionably prove very valuable to the average engineer, and the reviewer finds the collection one of the most comprehensive to be found anywhere in the literature.

It is regrettable that the word oscillograph has not been used instead of the term oscilloscope. The former is the more erudite term of the two and is undoubtedly to be preferred in scientific literature. Surely, the term oscillograph was the first word applied to the particular instrument, and an investigation of early writers on the subject will disclose its preference over all other terms. It was used, for instance, by J. B. Johnson in 1922 in the *Journal of the Optical Society of America* to describe "A Low Voltage Cathode-Ray Oscillograph," the first known practical instrument of this kind. A great many early references to the oscillograph are given in *The Cathode-Ray Oscillograph in Radio Research*, published by His Majesty's Stationery Office in London in 1933, and there is no reference to the word oscilloscope. This latter term has been widely used in the radio service field, but has not found great favor among engineers who are daily engaged in the study or design and development of cathode-ray oscillographs. This misuse of a word does not detract from the excellence of the material covered.

In summarizing, the reviewer has found this book to be an exceptionally fine reference work on the subject of cathode-ray oscillographs and their uses, and does not hesitate to recommend it as a valuable addition to engineering libraries everywhere.—*Scott Helt*, Research Div., Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N.J.

Progress in Photography—1940–1950

Editor-in-Chief, D. A. Spencer. Editorial Board, W. F. Berg, J. Eggert, L. E. Varden and T. A. Vassy. Published (1951) by The Focal Press, Ltd. Distributed by L. E. Varden, Pavelle Color, Inc., 533 W. 57 St., New York 19. 450 pp. + 10 pp. appendix. 150 illus. 7 × 9½ in. Price $10.00.

In 81 reports, 68 authors have recorded the progress of a decade in this volume. Some of their names are quite familiar to *Journal* readers. The opening article is by Glenn Matthews; E. W. Kellogg reports on sound recording; John Crabtree on processing; John Bradley on film storage.

The broad base of photography is covered by this book, with little detail given on any single phase; however, liberal reference lists are appended to each chapter.

Equipment progress is reported in terms of amateur equipment. There are some references to professional equipment. The new high-acetyl cellulose acetate film base gets one short chapter. Articles or chapters which include primarily motion picture subjects are: High-Speed Photography; Sound Recording for Motion Pictures; Recording with Galvanometer Oscillographs; Cine Radiography; Visual Aids for Instruction; Time and Motion Study; Job Training; Propaganda, Selling Aids and Demonstration Films; and a description of the functions and activities of the SMPTE.

It should not be assumed, however, that these reports have interest for only the motion picture engineer. Considering the broad base of our membership we counted 53 articles out of the 68 which have direct information bearing on some phases of our work.

Perhaps it is too much to ask, with so many subjects crowded into less than 500 pages, that a less selective annotation of equipment be employed! As we read some subjects we find, or sense, a partiality toward certain manufacturers. Important developments of competitors were not always reported. The editor might have condensed the three references or descriptions of the Polaroid Land camera to a single entry and added a few other interesting developments in the inches he gained.

The comment above, incidentally, applies to non-U.S. contributors as well as to

our compatriots. (About a third of the authors are American.)

Progress in Photography—1940–1950 should be a handy reference book with its international basis, especially when supplemented by the more detailed progress reports which appear in our *Journal.* It provides quick information on progress in England and Europe as well as our own, and the generous references will be of definite aid to the researcher. Its shortcomings are outweighed by the more positive aspects of the book, and readers may well find it a useful tool. The illustrative material is scanty but perhaps adequate.—*Don Bennett,* Associate Editor, Photo Dealer Magazine, 251 Fourth Ave., New York 10.

The Illumination of Photographic Darkrooms and the Determination of the Spectral Sensitivity of Photographic Material

By G. Weber. Translated from Danish into English by Vibeke Bonde. Published (1950) by the Academy of Technical Sciences and the Institution of Danish Civil Engineers on commission by G. E. C. Gad, 32 Vimmelskaftet, Kobenhavn K., Denmark. 280 pp. including appendix, bibliography and 12 pp. index. 166 illus. $6\frac{3}{4} \times 9\frac{3}{4}$ in. Paper cover. Price Danish Kr. 16,50 (about $2.00).

G. Weber, Professor of Illuminating Engineering at the Technical University of Denmark and President of the Danish Illuminating Engineering Society, has investigated the theory applicable to a judgment of what is the maximum light tolerable to photographic materials and the minimum light needed for adequate working conditions.

The author brings out the fact that darkroom illuminating should be chosen with regard to both the spectral sensitivity of the photographic materials to be handled and the sensitivity of the eye and that both of these sensitivities should be determined at the low intensities commonly used. In most cases this will require a source and filter combination.

The author states "...that the filters should have maximum efficiency, i.e., their absorption must be such as to cause minimum reduction of the light in relation to the eye and maximum reduction in relation to the plate." Theoretical consideration and calculations are discussed at considerable length and illustrative examples presented in unusually great detail. Some, but much less, attention is paid to practical trial methods. Under the heading "Direct Determination of the Permissible Illumination," there is recognition of the fact that in general the individual theoretical factors will not be precisely known. The statement, "None of these seven factors are known with any great certainty," is given as one reason for use of an experimental method. Again it is stated of the theoretical method presented, "But even if all these quantities were known, the method is of course far too complicated for practical purposes, although it may be of a certain theoretical interest."

This reviewer concurs in Dr. Weber's judgment; judged by this criterion, there are many, many pages "of a certain theoretical interest" and relatively few pages devoted to procedures intended for "practical purposes."—*D. R. White,* Research Laboratory Director, Photo Products Dept., E. I. du Pont de Nemours & Co., Inc., Parlin, N.J.

Audio Anthology

Compiled from *Audio Engineering,* C. G. McProud, Editor. Published (1950) by Radio Magazines, 342 Madison Ave., New York 17. 124 pp. incl. 210 illus. $8\frac{1}{4} \times 9\frac{3}{4}$ in. Price $2.00.

This compilation of 38 articles from *Audio Engineering* covers the period from May 1947 to December 1949. The selection of material has been largely directed toward the audio hobbyist. Eleven of the articles are on audio amplifiers. The remainder are on the subjects of loudspeakers, dividing networks, equalizers, noise suppressors, volume expanders and radio receivers.

Since the compilation is directed toward the audio hobbyist, the accent is on practical construction rather than on theoretical design considerations. However, when design information is necessary for the purpose of the article, it is presented in an understandable and usable form, as for

example in the articles on loudspeaker enclosures, dividing networks and multiple-speaker matching. The amplifiers described cover the range from phonograph preamplifiers to 30-watt power amplifiers. A considerable amount of space (10 articles) is devoted to the subject of frequency equalization, giving it a thorough coverage from a practical standpoint.—*G. W. Read*, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

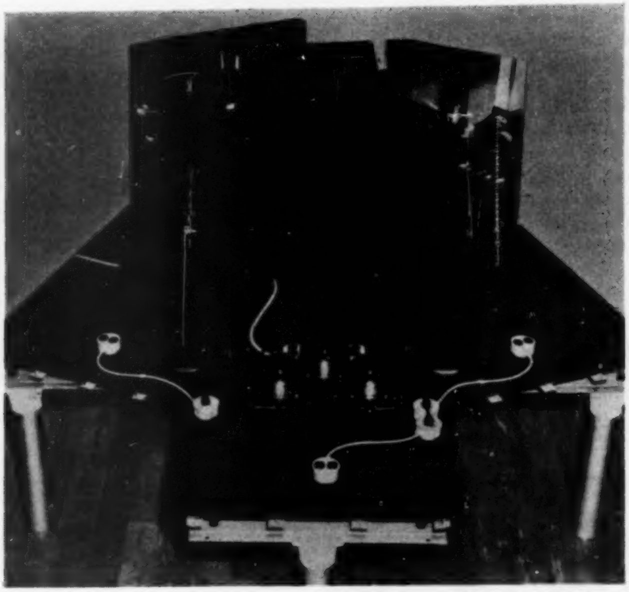
Bibliography on Stereography

Four hundred references have been published in mimeo form by the Stereo Society of America, covering magazines and journals from this country and from abroad. The references have a wide range—from editorials and popular articles to learned treatises. Copies of the Bibliography are available at $1.50 each from The Stereo Society of America, Inc., Owen K. Taylor, Secretary, 40 Monroe St., New York 2.

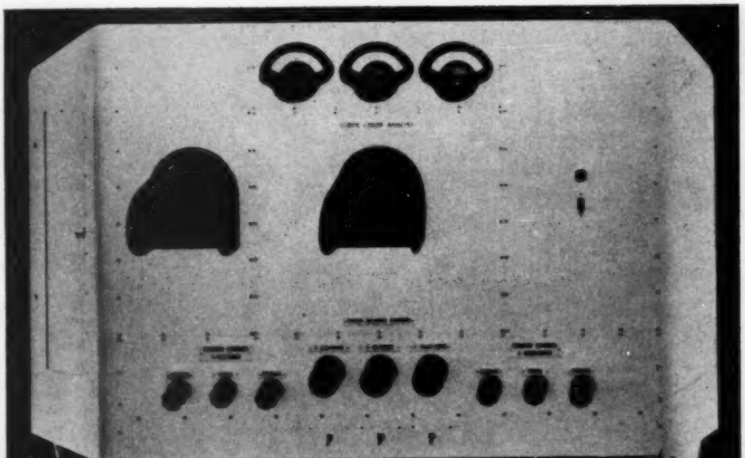
New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

Trade-marked the "Color-Tru Optical Bench," this equipment has been designed to enable the operator to judge intelligently the quality of photographic objectives and lens systems for most aberrations. Results are read directly by dial indicator in thousandths of an inch for comparisons between lenses. Attachments are available for holding cameras in alignment, nodal slide, lens boards and lens barrels. Targets are those of the U.S. Bureau of Standards. Checks can be made of resolution, color, focus, diaphragm location, effective aperture, cell separation, spherical aberration, element alignment and distortion. Prices range from $237.50 to $650.00, depending on accessories and on choice of microscope. The Color-Tru Optical Bench is available from Grover Photo Products, 2753 El Roble Dr., Los Angeles 41.



Curtis Color Analyst



Curtis Color Analyst

Color separation images may be evaluated, and any necessary corrections determined, with the **Curtis Color Analyst,** an instrument developed and manufactured by Curtis Laboratories, Inc., 2718 Griffith Park Blvd., Los Angeles 27, Calif.

The Color Analyst contains an optical system incorporating a beam splitter that enables the operator to see a fused image in color of three positive black-and-white separation images placed into the instrument, and illuminated by appropriately filtered light. Positive transparencies are required for the 11 × 14 in. Color Analyst or smaller models; black-and-white prints are needed for the large models. The intensity of any of the three illuminants may be varied to adjust the color balance of the image until it appears normal to the operator. The extents of such variations are indicated by means of dials or meters calibrated in terms of exposure variations required to obtain balanced color reproduction from any given set of separations. The light sources and filters may be chosen to match most nearly the characteristics of the inks, pigments or dyes of the final color reproduction process.

A 20 × 24 in. model of the Color Analyst has been built for the *Milwaukee Journal* where it is used to check color separation prints and black-and-white ink proofs.

Erratum

"Progress Committee Report," *Jour. SMPTE*, vol. 56, p. 568, May 1951.

Page 570, in title of Fig. 1 and in column 2, line 18: read *Camerette* for *Cameflex*. (This 16-/35-mm camera is known as the Cameflex in Europe but in the United States is the Camerette, according to new information from the Benjamin Berg Agency, 1213 North Highland Ave., Hollywood 38, Calif.)

Meetings of Other Societies

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

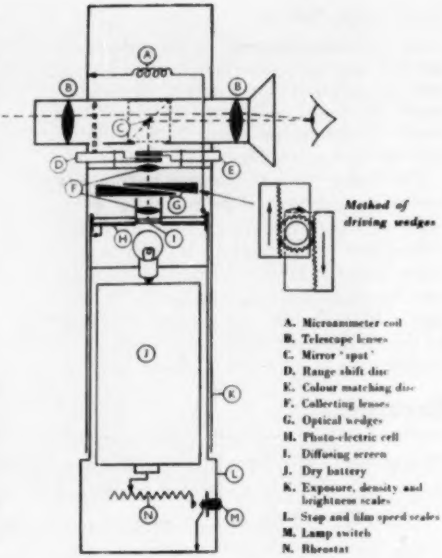
National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

- Acoustical Society of America, Oct. 23–25
- Optical Society of America, Oct. 23–25
- Society of Rheology, Oct. 24–26
- American Physical Society, Oct. 25–27
- American Association of Physics Teachers, Oct. 25–27

UFPA Fifth Annual Workshop

On August 13–18 the University Film Producers Association held its fifth annual workshop on the campus of Indiana University. There was a formal program of panels on production problems such as scripting, sound techniques, films for television, distribution and animation as they affect the university film producer. Screenings of university productions were held at night. Housing was provided in one of the University dormitories. Arrangements were under the direction of Harold Otwell, Audio Visual Center, Indiana University, Bloomington, Ind.



The Visual Photometer is a pocket-size visual-comparison photometer, with a brightness range of 1,000,000 to 1 and its own internal comparison source, made in England by Salford Electrical Instruments, Ltd. Zoomar Corp., 381 Fourth Ave., New York 16, is the distributor in the United States. The motion picture industry finds application for the SEI instrument in the production studio or on location for determining correct exposure and screen brightness in projection. A photocell and microammeter together with a potentiometer in the comparison lamp circuit provide a reference brightness adjustment independent of the brightness or color sensitivity of the observer's eye. Aging of the dry cell is thus compensated for.

A pair of neutral density wedges gives the instrument a basic brightness range of 100 to 1 and additional filters shift the range up or down by factors of 100 giving extended foot-Lambert range of from 0.01 to 10,000. Two filters, one blue and one yellow, change the apparent color of the comparison spot to match the incident light color when reading brightness of an object illuminated in the first case by the sun, high-intensity carbon arc or "daylight" lamps, or in the second case by tungsten lamps or the "low-intensity" type of arc lamp.

In use the comparison spot appears superimposed upon the object whose brightness is being measured. The wedges are then moved slowly until the spot blends into the background. By appropriate choice of scales it is then possible to determine either brightness of the object in foot-Lamberts, or photographic exposure required. Since the spot subtends an angle of one-half degree, readings of small areas at inaccessible places such as drive-in theater screens, walls, ceilings and drapes that surround the screen in a motion picture theater and high parts of studio sets are "naturals" for the SEI instrument.

Back Issues of the Journal Available

Three and one-half years of the Journal, July 1947 through December 1950, are available at the job lot price of $25.00 from Mr. Max Prilik, c/o Circle Theater, 82 H Grant Circle, The Bronx 60, N.Y.

Society of Motion Picture and Television Engineers

40 West 40th Street, New York 18, N.Y. Tel. LOngacre 5-0172
Boyce Nemec, *Executive Secretary*

Sustaining Members

OF THE

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Altec Companies
Ansco
Audio Productions, Inc.
Bausch & Lomb Optical Co.
Bell & Howell Company
Bijou Amusement Company
J. E. Brulatour, Inc.
Buensod-Stacey, Inc.
Burnett-Timken Research Laboratories
Byron, Inc.
The Calvin Company
Cinecolor Corporation
Cineffects, Inc.
Geo. W. Colburn Laboratory, Inc.
Consolidated Film Industries
Helene Curtis Industries, Inc., Natco Division
DeLuxe Laboratories, Inc.
Du-Art Film Laboratories, Inc.
E. I. du Pont de Nemours & Co., Inc.
Eastman Kodak Company
Fabian Theatres
Max Factor, Inc.
Fordel Film Laboratories
General Electric Company
General Precision Equipment Corp.
- Ampro Corporation
- Askania Regulator Company
- General Precision Laboratory, Inc.
- The Hertner Electric Company
- International Projector Corporation
- J. E. McAuley Mfg. Co.
- National Theatre Supply
- The Strong Electric Co.

Guffanti Film Laboratories, Inc.
Hunt's Theatres
Industrial Development Engineering Associates, Inc.
The Jam Handy Organization, Inc.
Kollmorgen Optical Corporation
March of Time
J. A. Maurer, Inc.
Mole-Richardson Co.
Motiograph, Inc.
Motion Picture Association of America, Inc.
- Allied Artists Productions, Inc.
- Columbia Pictures Corp.
- Loew's, Inc.
- Paramount Pictures Corporation
- Republic Pictures Corp.
- RKO Radio Pictures, Inc.
- Twentieth Century-Fox Film Corp.
- Universal Pictures Company, Inc.
- Warner Bros. Pictures, Inc.

Movielab Film Laboratories, Inc.
National Carbon
National Cine Equipment, Inc.
National Screen Service Corporation
National Theaters Amusement Co., Inc.
Neighborhood Theatre, Inc.
Neumade Products Corp.
Projection Optics Co., Inc.
Radio Corporation of America, RCA Victor Division
Reeves Sound Studios, Inc.
SRT Television Studios
Shelly Films Limited
Technicolor Motion Picture Corp.
Terrytoons, Inc.
Theatre Holding Corporation
Theatre Owners of America, Inc.
Titra Film Laboratories, Inc.
United Amusement Corp., Ltd.
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.